ADULT AND JUVENILE FISH, ICHTHYOPLANKTON AND BENTHOS POPULATIONS IN THE VICINITY OF THE J. H. CAMPBELL POWER PLANT, EASTERN LAKE MICHIGAN, 1977

By

D. J. Jude, B. A. Bachen, G. R. Heufelder, H. T. Tin,

M. H. Winnell, F. J. Tesar, J. A. Dorr III

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David J. Jude, Project Director

Great Lakes Research Division
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GENERAL INTRODUCTION

Due to the recent proliferation of power plants on Lake Michigan, much concern has risen from ecologists and the general public as to possible effects of these plants on the indigenous biota. The present report, which presents fish and benthos monitoring data collected during May-December 1977 in the vicinity of the J. H. Campbell Plant (fossil fuel: 647 mw) located on Pigeon Lake near Port Sheldon, Michigan (Ottawa County), should provide necessary data to help answer these questions.

The Campbell Plant is owned and operated by Consumers Power Company of Michigan and at present, has two generating units on line. The plant is being expanded to three units with a combined capacity of about 1,400 mw and will utilize an offshore intake and discharge structure in Lake Michigan for the third unit (Consumers Power Company 1975).

The primary purpose of this study was to gather background data on the indigenous fish and benthos populations in the vicinity of the J. H. Campbell Plant. These 1977 data will also establish baseline information against which postoperational (offshore intake and discharge of Unit 3) fisheries and benthos data can be compared. The study was designed to answer a number of questions relating to the distribution of benthos and larval, juvenile and adult fish in the waterways potentially affected or to be affected by the once-through cooling mode of operation at Units 1, 2 and 3 of the Campbell Plant. For Units 1 and 2, water passes from Lake Michigan, through Pigeon Lake and then out to Lake Michigan again; Unit 3 will be cooled by water drawn directly from Lake Michigan through offshore intakes.

We established two transects of stations in Lake Michigan. One, the north transect, was established to monitor possible effects in the area now affected by the thermal discharge of Units 1 and 2 as well as establishing baseline data so evaluation of the offshore intake and discharge systems (now under construction) can be made. The second transect served as a reference and was established south of the plant out of the influence of any present or projected thermal plume. Adult and larval fish data were collected at these transects on a regular basis. The benthos sampling program in Lake Michigan was a pilot study designed to establish the number of replicates (based upon sampling variability) required for the regular monitoring program, as well as some baseline data.

In Pigeon Lake, stations were located in three distinct areas: Lake Michigan-influenced stations, those in adjacent, but undisturbed areas and those in the remote part of Pigeon Lake near Pigeon River. Stations were chosen in an attempt to establish the origin of entrained larvae, and whether or not Pigeon Lake acted as a spawning and nursery area.

Stations were also established to determine if Lake Michigan species utilized the lake and to gain knowledge about the distribution of benthic organisms by habitat type. To ascertain relationships between fish larvae present in the various locations and those entrained, a station was set up in the intake canal.

Entrainment samples were collected in the discharge canal using a plankton net which allowed us to establish the magnitude of larval fish losses under the following optimal conditions: little or no net avoidance was expected and only a short time was required to sample a large volume of water because of the high water velocity in the canal. A significant number of replicates (4) could be collected each diel period due to the short sampling time. Large volumes of water could more easily be filtered using a plankton net so pumps were not used in this study.

To assess the likelihood of Lake Michigan being an important spawning area for fishes in the area of the Unit 3 intakes and discharges, SCUBA observations were also conducted in the area. A mark and recapture study of piscivores (largemouth bass, northern pike) was also conducted in order to estimate the numbers of these important sport fish in Pigeon Lake. These data can then be used to determine the impact impingement of these fish had on native fish stocks in Pigeon Lake.

STUDY AREA

The J. H. Campbell Power Plant is located on the eastern shore of Lake Michigan in Port Sheldon Township (T6N, R6W) Ottawa County, Michigan (Fig. 1). Land immediately surrounding the 3.24 km^2 site is classified as "dune" area and is characterized by high sand dunes and bluffs (U.S. Army Corps of Engineers 1971). Within an 8 km radius of the plant, land is used primarily for agriculture and forestry. The aquatic habitat immediate to the plant exhibits considerable variation.

Situated directly south of the plant is Pigeon Lake, the natural collecting basin for the Pigeon River before it enters Lake Michigan. The drainage area of the Pigeon River (approximately 155 km^2) supplies an average flow of 1.12-1.26 m^3/sec to Pigeon Lake (Water Resources Commission 1968). The power plant water usage of 18.7 m^3/sec for cooling condensers causes the natural flow of Pigeon Lake into Lake Michigan to be directed through the plant. Lake Michigan water is thus used to supplement Pigeon Lake water which is then drawn into the plant and discharged (after being heated 9-10 C) by way of a canal approximately 1 km north of the entrance of Lake Michigan to Pigeon Lake. Two stone jetties (366 m long) were constructed at the entrance of Lake Michigan to Pigeon Lake to insure adequate flow of intake water to the plant. During winter months, this channel is kept from icing by recirculation of discharge water from the plant. Heated water is piped along the north jetty and released into the canal.

The shoreline of Pigeon Lake reflects the general use of the lake as a recreational resource. A public access boat ramp maintained by the Michigan Department of Natural Resources (MDNR), as well as privately-owned ramps and docks are used extensively during spring, summer and fall. Undoubtedly much of the navigational use of Pigeon Lake as a safe harbor (Port Sheldon) is due to its access to Lake Michigan. The depth of Pigeon Lake (0.3-1.2 m for more than one-third of its area) as well as its extensive aquatic vegetation precludes extensive use by all but shallow draft vessels. The deepest part of the lake, located in the western portion, is 7.5 m; there is a moderately deep channel (2.1-5.7 m) following the southern shoreline, which accomodates many docking facilities. Lake surveys conducted by MDNR as well as sporadic newspaper accounts indicate that Pigeon Lake is heavily fished in winter months with notable success. The river above Pigeon Lake also sustains a sport fishery. In October 1964, the river and its tributaries were treated to control sea lampreys. Stream surveys conducted by the MDNR in 1972 on Pigeon Creek (T7N,R16W) indicated a population of brown trout and some brook trout were present.

Our sampling stations were established so netting was performed in all major habitat types. Two stations in the far eastern section of

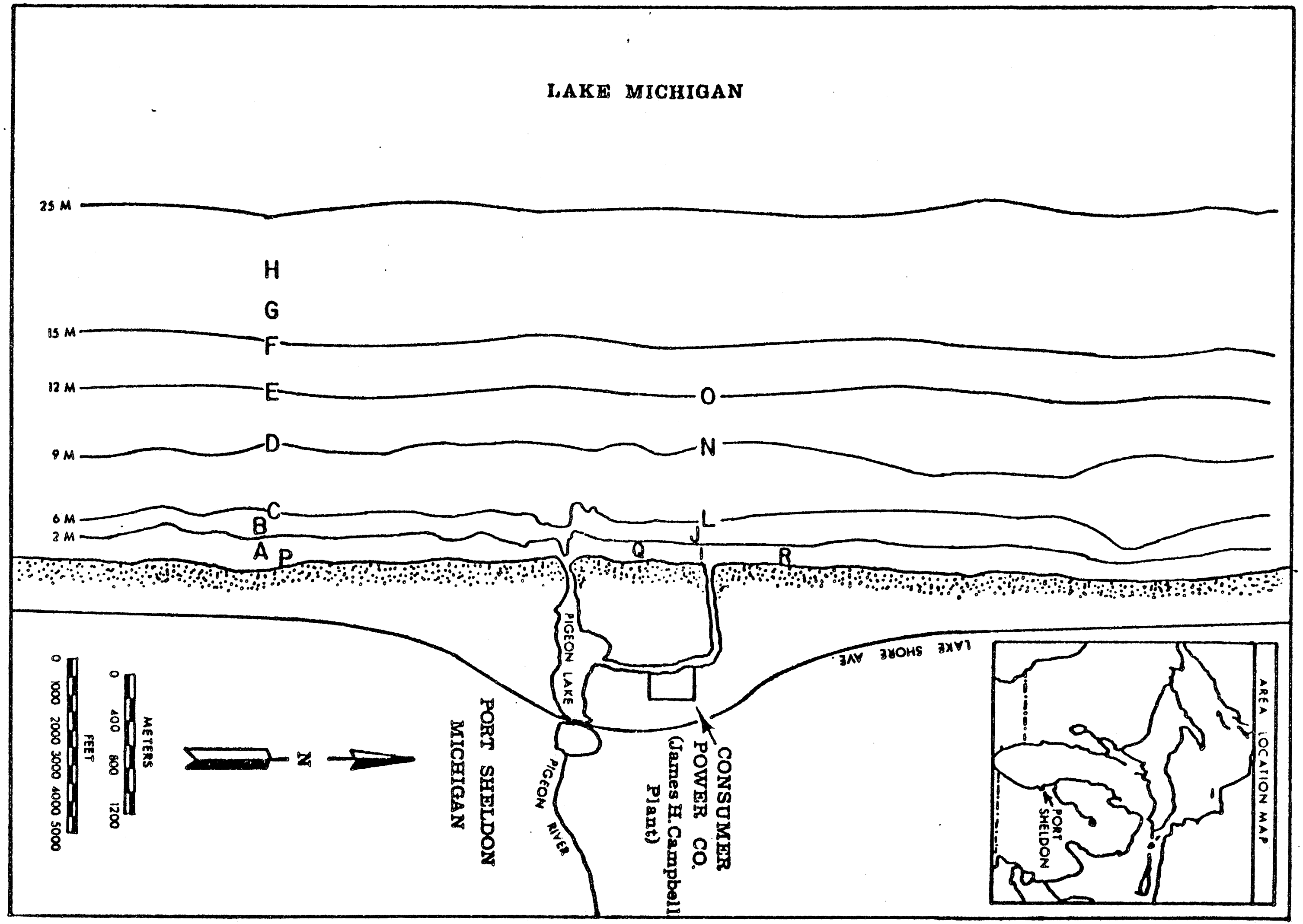


FIG. 1. Schemata of the J. H. Campbell Plant showing Lake Michigan and the 16 stations (A, B, C, D, E, F, G, H, L, N, P, Q, R, I, J and O) established for fisheries monitoring.

Pigeon Lake were chosen because of their proximity to the entrance of the Pigeon River. Station Y (Fig. 2) is an openwater station approximately 1.8 m deep. Aquatic vegetation in this area was extremely dense in summer and autumn and bottom- type was composed of soft peat (Consumers Power Company 1975). Beach station T (Fig. 2) was of similar bottom and vegetation type. Depth at this station ranged from 0.3 to 1 m with large obstructions (logs, branches, etc.) common.

The "undisturbed" part of Pigeon Lake was characterized by beach station V (and openwater station X). Vegetation density was notably less at these two stations when compared with stations Y and T, which had a similar bottom type. Openwater station (X) in this area ranged in depth from 1.2 to 2.1 m. Two additional stations (M and S), influenced by inflowing Lake Michigan water were also located in Pigeon Lake. Openwater station M (Fig. 2) was approximately 7 m deep and lacked dense vegetation observed at other Pigeon Lake openwater stations. Beach station S (Fig. 2) had a fine-sand bottom and steep slope, which restricted the width of seinable shoreline.

One openwater station was located in the intake canal (station Z - Fig. 2) which connects Pigeon Lake with the plant's present (Unit 1 and 2) cooling water system. This station was established to monitor fish larvae and eggs just before they are drawn into the power plant. The intake canal is approximately 670 m long and 21 m wide, with a maximum depth of 3 m.

Directly west of the plant is the shoreline of Lake Michigan. Again, this water resource finds extensive recreational and navigational use. Limited public entry to the Lake Michigan beach was possible through an access facility adjacent to the south side of the discharge canal. Fishing in the area of the discharge canal is popular throughout winter months due to attraction of fish to the discharge area. Swimming in the area of the discharge canal is prohibited due to unpredictable currents. Lake Michigan depth contours run roughly parallel to shore in the immediate area.

Eight openwater stations were chosen at a sequence of increasing depth contours 3.1 km south of the power plant in Lake Michigan (Fig. 1). This reference transect was chosen for its position outside the influence of the present and projected thermal plume and intake channel. Data from these stations are invaluable in describing the "normal" trends in fish distribution occurring in Lake Michigan. Stations A-H (south transect) ranged in depth from 1.5 m at station A to 21 m at station H, with intervening stations B-H separated by 3 m depth intervals.

Of the three Lake Michigan beach stations established, one (station P - Fig. 1) was chosen in the vicinity of the south openwater transect

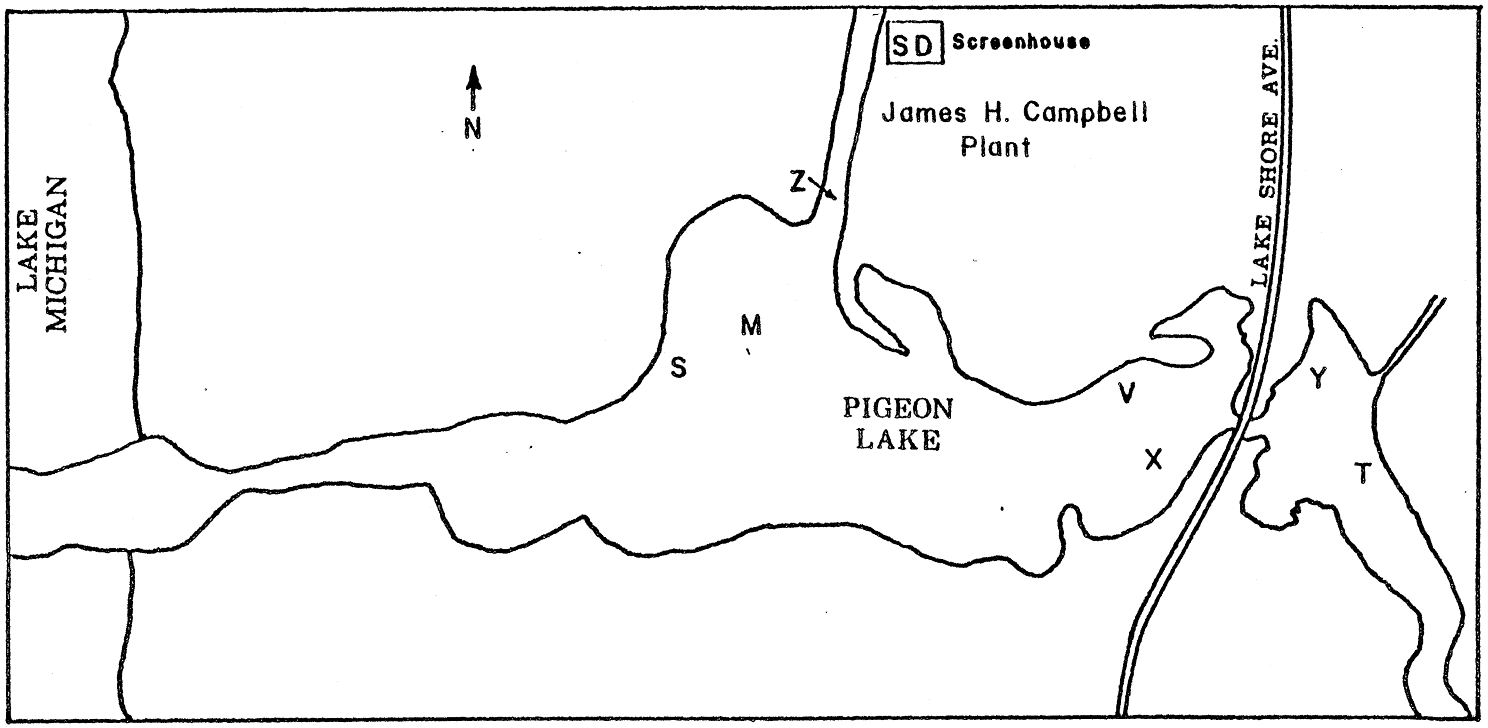


FIG. 2. Schemata of the J. H. Campbell Plant showing Lake Michigan and location of the seven fish sampling stations in Pigeon Lake (S, M, Z, V, X, Y, T) and the entrainment sampling location (SD) in the discharge canal of the Campbell Plant during 1977.

(approximately 3.1 km south of the plant) to act as a reference station in the shoreline area. The two additional stations in the vicinity of the present discharge canal (station Q approximately 0.6 km south of the discharge and station R approximately 0.6 km north of the discharge - Fig. 1) aided in monitoring the present thermal plume and its effect on shoreline fish movements.

METHODS

SEINING

Seining was performed using a 0.6 cm (.25 in) mesh nylon seine, 15.2 m x 1.8 m (50 ft x 6 ft) including a 1.8 m (6 ft) bag. The seine was hauled parallel to shore for a distance of 61 m (200 ft). Duplicate non- overlapping hauls were performed both day and night at all seining stations. Monthly seining was performed from June through November at three beach stations in Lake Michigan and three beach stations in Pigeon Lake (Table 1 and Figs. 1, 2).

In Lake Michigan hauls were performed against the current, when possible. During times when waves and current did not permit seining against the current, hauls were made in the direction of the current. Pigeon Lake stations had very little current, and the direction of seining was northwest to southeast at station T, southwest to northeast at station V and north to south at station S.

GILLNETTING

Nylon experimental gill nets 36.6 m x 1.8 m (120 ft x 6 ft) were set once a month for approximately 12 hrs during daylight and 12 hrs during the night. Each gill net was composed of 12 panels, with each panel starting at 1.3 cm (.5 in) bar mesh and proceeding in 0.6 cm (.25 in) increments up to 7.6 cm (3 in) mesh, with the last panel having 10.2 cm (4 in) mesh. Two of these nets fastened end to end were set together and considered replicates. All gill nets were set parallel to shore in Lake Michigan and perpendicular to shore in Pigeon Lake. In Lake Michigan, bottom gill nets were set at the 1.5, 3, 6, 9 and 12 m depth contours on the reference transect 3.1 km south of the plant (also referred to as the south transect) and at the 6 m depth contour opposite the present discharge channel (Table 1 and Fig. 1). Surface gill nets, which were identical to bottom gill nets except for additional floats, were set in Lake Michigan at the 6 m depth contour at the south transect and off the present discharge channel. In Pigeon Lake, bottom gill nets were set at openwater stations Y (1.5 m) and M (6.0 m) (Table 1 and Fig. 2).

TRAWLING

Bottom trawling was performed monthly from June through December in Lake Michigan using the University of Michigan's R/V Mysis. All trawls were made at an average speed of 4.8 km/hr (3 mph). Duplicate 10-min hauls were performed at the 6, 9, 12, 15, 18 and 21 m depth contours on a transect 3.1 km south of the plant and at the 6 m depth contour

TABLE 1. Proposed monthly sampling series for adult fish at selected stations in Pigeon Lake and Lake Michigan near the J. H. Campbell Power Plant, south of Grand Haven, Michigan, 1977.

Station	Maximum Depth (m)	Beach Seining	Surface Gillnetting	Bottom Gillnetting	Bottom Trawling
Pigeon Lake					
M	6.0			X	
S	1.5	X			
T	1.5	X			
V	1.5	X			
Y	1.5			X	
Lake Michigan					
A	1.5			X	
B	3.0			X	X
C	6.0		X	X	X
D	9.0		X*	X	X
E	12.0		X*	X	X
F	15.0				X
G	18.0				X
H	21.0				X
L	6.0		X	X	X
P	1.5	X			
Q	1.5	X			
R	1.5	X			

X = duplicate sampling (seines, gill nets or trawls)

* = monthly sampling deleted after August

a transect 3.1 km south of the plant and at the 6 m depth contour between the present discharge channel and the Pigeon Lake entrance to Lake Michigan (Table 1 and Fig. 1). Hauls were performed at 3 m at the south transect during periods of reduced wave height. Trawling was done once during the day and once at night at all stations except the 18 and 21 m stations where only day trawling was done. A semi-balloon nylon otter trawl having a 4.9 m (16 ft) headrope and a 5.8 m (19 ft) footrope was used. The body and cod end of the net were composed of 1.9 cm (0.75 in) and 1.6 cm (0.62 in) bar mesh respectively, while the cod end interliner was 0.63 cm (0.25 in) stretch mesh. All trawl hauls were taken parallel to shore following the station depth contour. Two replicate samples were obtained at each station by once trawling south to north and then trawling north to south.

ADDITIONAL AND MISSING SAMPLES

The proposed monthly sampling series for Pigeon Lake and Lake Michigan consisted of 28 trawl hauls, 24 duplicate gill net sets, 8 duplicate surface gill net sets and 12 beach seine hauls. While it was hoped that proposed series fishing could be performed every month, this was not always possible due to equipment failure and inclement weather. Following is a summary of samples missing from the proposed monthly sampling series in 1977 (number of missing observations in parentheses):

1. June - night bottom gill nets at A, B, C, D, E and L (12), night surface gill nets at C and L (4).

2. August - night surface gill nets at C and L (4).

3. October - day and night bottom gill nets at A, B, C, D, E and L (24), day and night surface gill nets at C and L (8).

When feasible, additional samples beyond those of proposed monthly sampling were collected. Supplemental surface gill nets were set at 9 and 12 m stations along the south transect during the day in June and August and during both day and night in July. Supplemental day bottom gill nets were set in December at the 6 m stations on the south transect and off the present discharge canal. Also during December in Pigeon Lake, we set bottom gill nets at stations M and Y during the day and at station M at night.

Additional trawling at the 3 m, south transect station was done during the day in August, September, and November. Supplemental trawling was also performed at the 3, 6 and 9 m stations on the south transect and at the 6 m station off the discharge canal in December.

MARK AND RECAPTURE STUDY

To assess the population and relative loss due to impingement of game fish in Pigeon Lake a mark and recapture study was conducted. Species considered for the study included yellow perch, largemouth bass, smallmouth bass, northern pike, bluegill and black crappie. Since Pigeon Lake is an open system, a major factor in selecting species to study was to consider the amount of potential interchange between Lake Michigan and Pigeon Lake. Since fairly large numbers of yellow perch live in Pigeon Lake, too many would have to be marked to supply a good estimate; therefore this species was not studied. Migration of fish from or into Pigeon Lake would violate a basic assumption used in population estimates (Ricker 1975). The primary species employed in this mark and recapture study were northern pike, largemouth bass and smallmouth bass. From baseline survey work performed on Pigeon Lake by our research group, it was determined that bluegill and black crappie were present in fairly low numbers and thus could not be adequately assessed. Grass pickerel were marked because they were inadvertently collected along with northern pike.

An electrofishing boat (Coffelt Electronics Company Inc.-Model VVP-15) was used to collect most fish in the study. The generator was designed to deliver 300 V pulsating DC current to minimize the number of deaths due to shocking. Stunned fish were brought aboard by dip net and held in a live-well for recovery. Other gear used to capture fish were gill nets and seines. Fish from gill nets that were judged to be in good condition (i.e. able to swim away) were marked and released. Some fish from seines were also tagged and released. Fish taken by seine and gill net were included in the catch of that period along with the electrofishing catch. Northern pike greater than 299 mm total length and largemouth bass greater than 219 mm total length were tagged with spaghetti tags. The smaller northern pike and largemouth bass, along with all grass pickerel and smallmouth bass, were fin clipped using a different pelvic or pectoral fin for each period. Spaghetti tags (Floy Tag & Manufacturing, 4616 Union Bay Place Northeast, Seattle, Washington 98105) were individually numbered and contained the address of the Consumers Power Company in Jackson, Michigan. Tags were inserted in the epaxial muscle below the dorsal fin.

Fish were marked during four periods between 21 September 1977 and 3 November 1977. These periods ranged from 2-4 days long. Most shocking was done at night because of higher catch-per-unit-effort. Each trip lasted 4-9 hrs. Shallow areas (less than 1 m) of Pigeon Lake were thoroughly covered during the first two periods. From this experience it was learned where pike and bass were commonly found in the lake. These areas were covered during electrofishing from then on and no effort was expended in areas containing few or no pike and bass. Areas which contained high concentrations of fish varied from one

collection period to the next and were heavily fished when encountered. Because Pigeon Lake gradually narrows at its upstream end to become Pigeon River and the distinction is by no means exact, an arbitrary upper boundary was designated (Fig. 3). Fish may have moved in and out of the area designated as Pigeon Lake into the Pigeon River or vice versa, but this effect was assumed to be minimal.

Pigeon Lake was divided into nine areas depicted in Fig. 3. When fish were tagged the species, length, weight and area of capture were noted. Recaptured fish were examined for tag number and this information recorded with the area of capture. To assess angling mortalities, a collection box was established at the MDNR launching area to recover tags in fish caught by fishermen. No tags were found in the box, but the box had been vandalized. Observations made during the study period in the Pigeon Lake area indicated no fishing success among the few fishermen seen. Thus, it was assumed that fishing mortality was low enough to satisfy assumptions necessary to make a population estimate (Ricker 1975).

FISH LARVAE TOWS

Fish larvae, arbitrarily defined as any fish less than 2.54 cm total length, were collected using a 0.5 m diameter, nylon plankton net of No. 2 mesh (351 micron aperture). Larvae were sampled in Pigeon Lake, Lake Michigan and the intake canal of the Campbell Plant. Entrainment samples were taken from the discharge canal of the Campbell Plant. A Rigosha flowmeter (Rigosha and Co. Ltd., 10-4 Kajicho 1-Chome, Chiyoda-Ku, Tokyo, 101 Japan) attached to the center opening of the plankton net determined volume of water sampled. When flowmeters were not available or stopped functioning, average flowmeter values were computed from readings available from the same station at other times or from stations of comparable depth. Suspect flowmeter readings were deleted when accuracy was questionable. Out of 1,084 fish larvae samples collected in 1977, 162 either had no flowmeter readings or readings were suspect and required the computation and insertion of an average flowmeter reading. Many of the suspect or lost readings were from beach tows collected in Pigeon Lake. These stations were choked with aquatic macrophytes during most of the summer making net towing without fouling by plants extremely difficult.

Missing flow meter readings fell into three broad classes. The first class consisted of Pigeon Lake samples in which the flowmeter became clogged. The second class consisted of Lake Michigan samples for which no flowmeter was available. The third class consisted of duplicate tows for which no flowmeter was available for one of the two nets; however a meter was available for the other replicate. Missing readings for these classes were handled as follows:

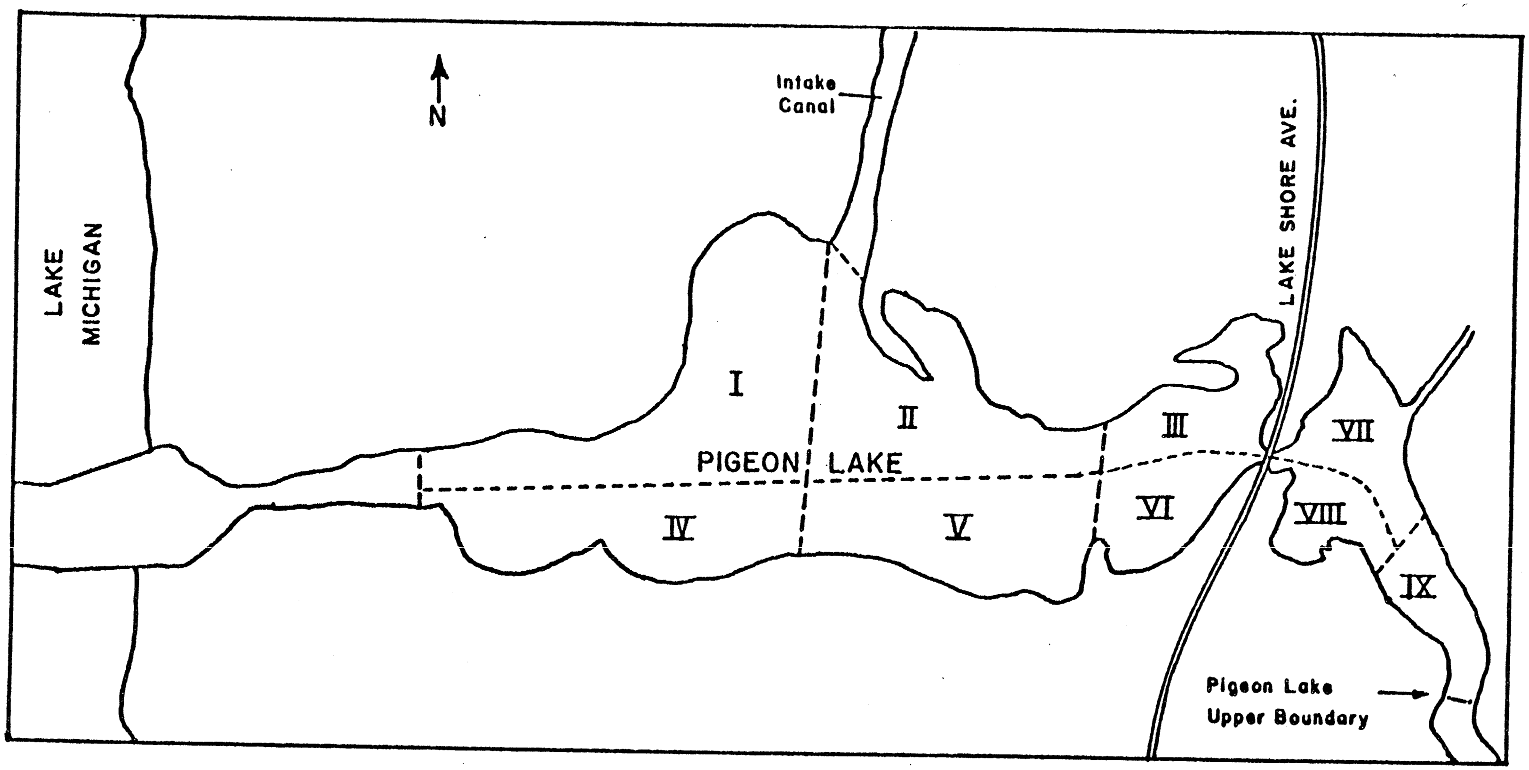


FIG. 3. Schemata of Pigeon Lake showing the location of nine electrofishing areas designated for the mark and recapture study conducted during fall, 1977 at the J. H. Campbell Plant.

(1) Class I: A grand average of flowmeter readings observed during early summer and late fall sampling in Pigeon Lake was substituted for the inaccurate flow meter readings.

(2) Classes II and III: A grand average of flowmeter readings taken over all months from Lake Michigan stations and openwater stations in Pigeon Lake was substituted for the missing flowmeter reading.

All meter revolutions were converted to volume filtered by letting 1 revolution = 15 liters.

Duplicate surface tow samples were collected at the seining stations in Lake Michigan (P, Q and R - Fig. 1) and Pigeon Lake (S, T and V - Fig. 2). Three people simultaneously hand-towed two nets for a distance of approximately 61 m (200 ft) once during the day and once at night. Beach tows were performed twice in June, three times in July and once in August, September, October and November.

Horizontal 5 min fish larvae tows were also performed at discrete depths parallel to shore at the remaining three stations in Pigeon Lake (M, X and Y), 13 stations in Lake Michigan (A, B, C, D, E, F, G, H, I, J, L, N and O) and one station (Z) in the intake canal (see Table 2 for actual depths sampled at each station). Sampling at stations I, J, N and O was initiated on 13 July. Openwater fish larvae samples were collected from these selected stations in Lake Michigan during day and night twice in June, three times in July and once in August and September. One surface tow was collected at station L in December. Additional Lake Michigan samples were collected on 13 July by Consumers Power personnel at north beach station R (n. discharge) as well as north transect stations I (1.5 m - n) to O (12 m - n). Samples taken at this time however, were taken at different depth intervals than our standard sampling (Appendix 7). Openwater tows were collected from selected stations in Pigeon Lake twice in June, three times in July and once in August, September, October, November and December. Equipment failure and inclement weather occasionally prevented completion of this sampling schedule. Missing samples included day and night tows at station X between 7-10 July and night tows at stations G and H between 19-23 September.

Larvae tows from Pigeon Lake and the intake canal were collected from a 6 m long outboard motor boat. Openwater fish larvae tows in Lake Michigan were collected from the University of Michigan's R/V Mysis as follows:

1) plankton net with attached mason jar and depressor lowered to desired depth (average ship speed: 3-6 kph or 2-4 mph)

TABLE. 2. Fish larvae sampling depths (m) from selected stations in Pigeon Lake and Lake Michigan near the J. H. Campbell Power Plant, Port Sheldon (south of Grand Haven), Michigan, 1977.

	Pigeon Lake				Lake Michigan												
Stations:	Y	M	X	Z	A	B	C	D	E	F	G	H	I	J	L	N	O
Tow Depth(s):	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
		2.5		2.5		2.5	2.0	2.5	3.0	4.5	4.0	5.0		2.5	2.0	2.5	3.0
		4.5					4.0	4.5	6.0	8.5	9.0	10.0			4.0	4.5	6.0
							5.5	6.5	9.0	11.5	14.0	15.0			5.5	6.5	9.0
								8.5	11.0	14.0	17.0	20.0				8.5	11.0
Maximum Depths:	1.5	6.0	2.0	3.0	1.5	3.0	6.0	9.0	12.0	15.0	18.0	21.0	1.5	3.0	6.0	9.0	12.0

2) plankton net towed horizontally for 5 min starting at the desired depth which was obtained by measuring wire angle and geometrically calculating the amount of cable to be released to reach desired depth

3) plankton net hauled to surface and washed using a hose from the Mysis

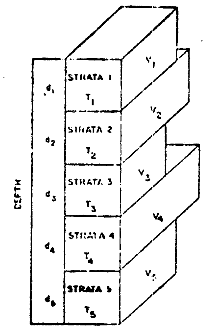
4) contents rinsed into the wide-mouth glass (0.47 liter) mason jar, formalinized (40 ml buffered formalin), labeled and sealed

Total numbers of larvae captured in all tows (other than surface tows) were adjusted to compensate for upper strata contamination. The adjustment procedure is outlined in Figure 4. The method consists of sequential subtraction of larvae from lower water depth levels based upon concentrations observed in upper water strata. We assumed that larvae were homogeneously distributed within a water stratum and that nets passing through a particular stratum from a lower level would catch larvae in proportion to the volume of water filtered. Larvae from all tows conducted below the surface stratum which were probably caught during the vertical haul following termination of the horizontal tow, were removed from calculations of total larvae present. We assumed that contamination occurring while the net was being lowered was negligible. The effects of differential vertical distribution due to larvae size was mitigated be stratifying each sample into 0.5 mm length intervals. A total of 51 length intervals were defined for fish larvae.

Vertical net hauls, conducted in a 2.6 m deep swimming pool, were used to estimate the volume of water filtered per meter of vertical tow. Mean volume filtered was 0.48 m^3 (28 $\pm$ 0.52 S.E. revolutions) yielding a correction factor of 0.18 m^3 water filtered/m of vertical haul. An example of this adjustment procedure is presented in Table 3.

SLED TOWS

Bottom tows were performed with a benthic fish larvae sled equipped with a flowmeter (Fig. 5). A single 5 min sled tow was performed once during the day and once at night at all stations in Lake Michigan when time and weather permitted. Day and night sled tows were conducted at priority stations (those permitted). Day and night sled tows were conducted at priority stations (those closest to the present discharge) in July and September. Only day sled tows were performed at these stations in August and October.



CALCULATION PROCEDURE:

1. Convert current meter reading to volume filtered (V_i)
2. Stratify total larval (T_i) catch for each sample depth interval, into n 0.5 mm length intervals denoted by $N_{i,m}$.

   Thus, $T_i = \sum_{m=1}^{n} N_{i,m}$
3. Calculate average concentration of larvae of length class m in the first stratum for all m.

   Thus, $\bar{C}_{1,m} = (N_{1,m}/V_1)\ 1000$
4. Begin interative calculation of adjusted average concentrations of larvae for each depth stratum where

$$\bar{C}_{i,m} \begin{cases} \dfrac{1000[N_{i,m} - \mathrm{trc}\ (0.18(\sum_{j=1}^{i-1} d_j\ \bar{C}_{j,m})/1000)]}{V_i - 0.18 \sum_{j=1}^{i-1} d_j} = a \text{ if } a > 0 \\ 0 \text{ otherwise} \end{cases}$$

where d_i = vertical depth of water in the i-th water stratum

D = total depth of water column $D = \sum_{i=1}^{5} di$

T_i = total uncorrected catch of larvae in the i-th water stratum.

$N_{i,m}$ = total uncorrected catch of larvae of the m-th size class caught in the i-th water stratum.

V_i = estimates volume of water filtered by net towed in stratum i.

(0.18) = correction factor expressed in terms of volume of water filter per meter of vertical tow.

i.e. $\text{units} = \dfrac{H_2Om^3}{m} = H_2Om^2$

trc(·) = function which truncates argument to nearest non-negative integer number.

$C_{i,m}$ = adjusted average concentration of larvae of the m-th length class in the j-th depth stratum.

FIG. 4. Schematic representation of adjustment calculations for upper level contamination in larvae samples. Blocks represent varying quantities of water filtered in 5 different water strata.

TABLE 3. Example of computational procedures used to correct larvae samples for upper level contamination. Refer to Figure 4 for definition of terms. Data values are hypothetical.

Tow Depth (m)	Height of Stratum (m) d_i	Volume of Water Sampled V_i (m^3)	Actual Total Larvae Caught Ti	Length Interval m	Actual Number of Larva Caught Ni, m	Uncorrected Concentration $(N_{i,m}/V_i)1000$	Corrected Concentration $\bar{C}_{i,m}$
0	2	30	500	6.6-7.0	200	6666	6666
				10.1-10.5	100	3333	3333
				15.1-15.5	100	3333	3333
				20.6-21.0	100	3333	3333
2	2	25	3	*6.6-7.0	1	40	0
				9.0-9.5	1	40	40
				13.6-14.0	1	40	40
4	2	20	7	7.1-7.5	1	50	51
				8.1-8.5	1	50	51
				*10.1-10.5	2	100	52
				21.1-21.5	1	50	51
				22.0-22.5	2	100	103
6	2	10	12	6.1-6.5	2	200	224
				*6.6-7.0	1	100	0
				*10.1-10.5	3	300	112
				10.6-11.0	2	200	224
				*15.1-15.5	4	400	336
				18.6-19.0	2	200	224
				20.1-20.5	1	100	112

* Adjustment for upper strata contamination performed.

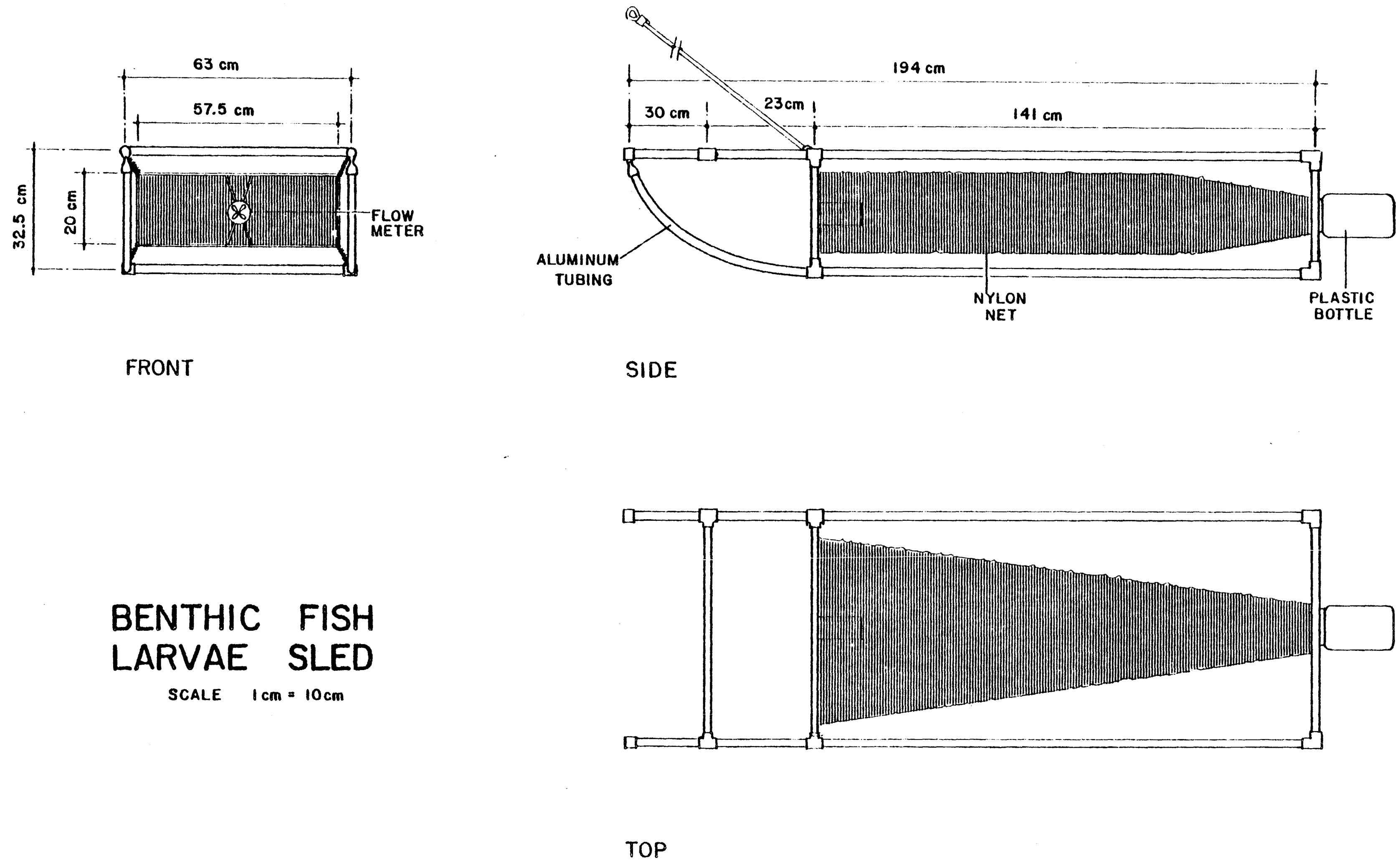


FIG. 5. Benthic fish larvae sled used to collect demersal larval fish. A No. 2, nylon 0.5 m diameter plankton net and Rigosha flowmeter were mounted on the aluminum frame as shown. A pint mason jar, fastened to the net by screwing into a permanently mounted wide mouth jar ring for ease of removal, was inserted into the plastic bottle to prevent damage to the jar.

ENTRAINMENT

Design of the entrainment sampling scheme for the Campbell Project was based on previous experience and physical structure of the intake and discharge forebays at the plant. Condenser cooling water for the Campbell plant is drawn from Pigeon Lake and Lake Michigan via an intake channel connecting the plant's present intake structure and the north shore of Pigeon Lake. After passage through either Unit 1 or Unit 2 condensers, cooling water is discharged to Lake Michigan via a discharge channel approximately 1,100 m long, 21 m wide and 2.1 m deep. Water is heated approximately 9-10 C (Consumers Power Co. 1975), then discharged. Weekly entrainment sampling was performed at the condenser discharge (velocity: 1.83 m/s) canals. A 0.5 m diameter plankton net equipped with a flowmeter was lowered into a condenser discharge canal of either Unit 1 or Unit 2 (contingent upon operation) for 10 min. A heavy weight (18 kg) was necessary to keep the net below the water surface. Four (sometimes five) replicates were taken once during the day and once at night on a weekly basis from July to December. All samples were immediately preserved in 10% buffered formalin.

Entrainment results were presented as number of fish eggs or larvae entrained per diel period derived by the formula:

$$N = \frac{C \times V \times T}{24}$$

where:

- N = number of fish eggs or larvae entrained per diel period.
- C = concentration of fish eggs or larvae entrained per 1000 m^3 (see Fish Larvae Processing).
- V = Volume of water in thousands of m^3 pumped by the plant during the 24 hr period. (These data were provided by Consumers Power.)
- T = Number of hours of each diel period at the sampling site located at approximately 43° N latitude. The number of daylight hours is considered to be the period between the beginning of twilight (a.m.) and the end of twilight (p.m.). Twilight times were taken from the American Ephemeris and Nautical Almanac for 1978 (U.S. Nautical Almanac Office 1976). The number of hours of darkness is equal to 24 minus the number of daylight hours.

The above calculations were based on the following assumptions:

(1) The pumping rate remains constant throughout the 24 hr period. Consumers Power personnel, however, indicated that the actual pumping rate may be significantly different between day and night. This difference will be taken into

account in the 1978 report.

(2) The concentration of eggs or larvae entrained remains the same during each diel period. Variations of this concentration may, however, occur during each diel period. The new sampling scheme adopted for the 1978 study will provide necessary data to detect such variations and enable a better estimation of number of eggs or larvae entrained.

FISH LARVAE PROCESSING

Fish larvae and eggs were removed from samples with the aid of a binocular scope and a lighted sorting chamber (Dorr 1974). Larvae were usually measured to the nearest 0.1 mm (total length), though in large samples larvae were sometimes measured to the nearest 0.5 mm. Larvae and egg data were entered on coding forms and later keypunched. Numbers of larvae and eggs captured were adjusted to number per 1000 m^3 via a computer program. Knowledge of fish spawning in Lake Michigan, specimen comparisons and the taxonomic works of Dorr et al. (1976), May and Gasaway (1967), Mansueti and Hardy (1967) and Fish (1929) were useful in larval fish identification. We stress for this report that many of the fish larvae identifications remain tentative. We hope to be able to review all our identifications based on some newly acquired works on larval fish, knowledge of what adult species were found during our surveys and what species (once they were large enough to easily identify) were predominant in our late season larval collections.

For this report, we have tentatively designated all clupeids as alewife. Alewife and gizzard shad larvae are difficult to separate and since gizzard shad adults are common in the area, some of our alewives may be shad. Young-of-the-year gizzard shad have not been found in Pigeon Lake and only appeared in the Lake Michigan samples in late September. The riverine habitat of the Grand River may be more desirable spawning area for gizzard shad since many YOY have been visually observed there. We hope to sample Pigeon Lake earlier this year (shad generally spawn earlier than alewives) and determine if gizzard shad spawn in the lake. One larvae from April 1978 entrainment samples has been tentatively identified as a gizzard shad.

FISH LARVAE TOTAL LENGTH-BODY DEPTH RELATIONSHIP

To help address the problem of what sizes of intake screening should be used to protect fish larvae from entrainment, we measured total lengths and body depths of some larval fishes common to Lake Michigan in the area around the J. H. Campbell Power Plant. Species evaluated included: alewife, burbot, carp, *Cottus* spp., johnny darter,

rainbow smelt, spottail shiner, trout-perch and yellow perch. The Great Lakes Regional Fish Larvae Collection housed at the Great Lakes Research Division, University of Michigan and field larvae samples collected between 1974 and 1978 near the J. H. Campbell and D. C. Cook Power Plants (Jude et al. 1975, 1979) were sources for specimens used. Most came from Lake Michigan or Pigeon Lake, but some burbot larvae (from Oneida Lake, New York) and some trout-perch larvae (from Douglas Lake, Michigan) from other areas were also included.

Body depth (measured at the point of greatest depth, including yolk sac) and total length of each fish larva were measured to the nearest 0.1 mm under a binocular microscope at 10X power. Scatter plots and simple linear regressions were performed for body depth vs. total length.

Slopes and y-intercepts generated by the regression analyses were used to calculate total length of larvae when body depths of 0.5, 1.0 and 2.0 mm were attained for each species. These length values were then compared to 1977 length-frequency data for the four most abundant species entrained at the J. H. Campbell Plant (Jude et al. 1978). From these comparisons, estimations were made of the percentage of fish larvae that would be excluded by various screen mesh sizes.

LABORATORY ANALYSIS OF JUVENILE AND ADULT FISH

Each replicate from seine, gill net and trawl catches was labeled and kept separate in plastic bags. Fish were processed fresh when time permitted, or otherwise frozen at the Campbell Plant or on board the R/V Mysis (trawl catches). For laboratory examination, fishes in each bag were thawed, separated by species, then grouped into size classes. When large numbers of a particular size class for an unusually abundant species were present, a subsample was randomly selected from the group and the remaining fish weighed (herein referred to as the mass weight) and discarded. The following data on each fish were recorded: total length (to the nearest mm, caudal fin pinched), weight (to the nearest 0.1 g) using a P1000 Mettler balance, sex, gonad condition, presence or absence of food in the stomach, fin clips, lamprey scars, evidence of diseases and parasites. Large fish and fish in the mass weight (over 1000 g) were weighed with a hanging scale spring balance (K023G Chatillon) to the nearest 20 g.

Gonad condition of adult fish was described according to five stages of development: 1) underdeveloped, 2) moderately developed - for female, eggs discernible but not fully ripe, 3) ripe, 4) ripe-running - sex products exiting with application of moderate pressure, 5) spent. Other gonad conditions recorded included: 6) immature, 7) unable to ascertain sex on adult fish, 8) reabsorbed eggs - for female fish, 9) fish decomposed or mutilated so that sex was impossible to determine.

All fish were identified to species using Hubbs and Lagler (1964), Trautman (1957), Scott and Crossman (1973) and Eddy (1957) with the exception of the genus Coregonus (subgenus Leucichthys). Satisfactory keys for this subgenus do not exist because of unsettled questions on the validity of several species (Scott and Crossman 1973) and the possibility of their introgression (Wells and McLain 1973). The only adult Leucichthys that can be positively identified is the lake herring, Coregonus artedii. Other Leucichthys, adult or juvenile, were pooled as unidentified coregonids (code XC). These were believed to be mostly bloaters, C. hoyi.

Due to the morphological similarities between the two species of sculpins present in our area, some Cottus bairdi may have been identified as Cottus cognatus. This problem of identification may be compounded by the possibility of hybrids and backcrosses (personal communication, Don E. McAllister, Curator of Fishes, Museum of Natural Sciences, Ottawa, Canada). Comparison and analysis of specimens collected in this first year will enable reliable separation of these closely related species in future work.

DATA MANIPULATIONS AND CALCULATIONS

For each adult and juvenile fish examined the following information was recorded on a 75-column coding form, one fish per line: date and time of sample, type of gear, day or night series, station, species code, a unique incrementing number, length, weight, sex, gonad condition and presence or absence of food in the stomach.

Data on subsampled fish were recorded on consecutive lines each having a subsampling code. Special columns were reserved for the corresponding mass weight. Computer programs searched for subsampled lots and calculated number of fish processed, their mean weight and the total number of mass weighed fish not examined. Mass weighed fish were proportionally assigned to length intervals based on the number of measured fish found in each length interval. Fish were divided visually by length into many narrow size classes when originally subsampled, to minimize error associated with this reconstruction of sample length frequencies.

Fisheries data were keypunched, then read onto computer disks and tapes. For the bulk of our statistical analyses we used the Michigan Interactive Data Analysis System (MIDAS) which was developed by the Statistical Laboratory of the University of Michigan. From our computer programs we obtained summary statistics on seasonal gonad condition, temperature-catch relationships catches by month, gear type, station and day and night series and length-frequency histograms.

Gill nets were set for as close to 12 hrs as possible when there was available daylight or darkness. Due to unpredictable weather conditions and changing day length, however, actual time gill nets were fished varied from 5 hr 10 min to 15 hr 25 min. Gill net catches for calculating statistics were adjusted to approximate numbers caught per 12 hrs by assuming that catch was a linear function of time. The above assumption is not completely valid as gill net catch per unit time might be expected to decrease as the net fills with fish, but increased accuracy could not justify the cost of determining a precise relationship for each species.

DEFINITION OF TERMS

Adult fish length intervals - for figures describing total lengths of adult fish, individuals were assigned to 10 mm intervals. For example, the 30 mm length interval would include fish from 26-35 mm.

Beach zone - refers to that area of water, usually less than 1.5 m, that is accessible to wading during seining and fish larvae sampling activities. Includes only beach stations.

Deepwater (profundal) - the portion of the lake characterized by gelatinous silt (mud) deposits (>6 m).

Fish larvae - any larval fish less than or equal to 25.4 mm in total length.

Fry - any fish greater than 25.4 mm in total length caught in plankton nets. Fish were usually 25-100 mm.

Inshore - refers to that area of water between the shoreline and 21 m.

Larval fish length intervals - for length-frequency histograms for larval fish, a specimen was assigned to 0.5 mm intervals based on total length. For example larvae 0.3 mm would be assigned to the interval 0.5 mm, one 5.6 mm would be assigned to the interval 5.6-6.0 mm.

Littoral zone - the portion of the lake from the shoreline to the deepest extent of rooted aquatic macrophytes (0-4 m).

Nearshore - refers to that area of water less than or equal to 3.0 m.

Offshore - another term for that area of water, not beach zone, 21 m deep or greater.

Openwater - refers to that area of water which is not beach zone and includes all stations 1.5 m and deeper which were usually sampled by boat and which usually had no or very few aquatic macrophytes present.

Sublittoral zone - the portion of the lake from the deepest extent of the rooted aquatic macrophytes to the regular occurrence of mud deposits (4-6 m).

Water temperature intervals - catch of adult fish was assigned to 2 C water temperature intervals for the purposes of establishing temperature-catch relationships. For example, the 3 C temperature interval would include fish caught between 2.0 and 3.9 C.

BENTHOS

Benthic samples were collected in Lake Michigan near the J. H. Campbell Plant on 4-5 June 1977. Seven transects parallel to shore in each of three 1.6 km (1.0 mile wide) regions (north, middle and south) were established in Lake Michigan in the vicinity of the Campbell Plant (Fig. 6). The middle region was centered on the present discharge channel and extended south and north a distance of 0.8 km (0.5 mile) from that point. The north and south regions were centered on a distance of 4.8 km (3.0 miles) from the discharge channel. These regions extended 0.8 km (0.5 mile) north and south of their central axis.

Each transect (Fig. 6) was sampled ten times at evenly spaced intervals 0.18 km (0.11 mile) apart. Parallel transects were established at the following depth contours: 3, 6, 9, 12, 15, 20 and 25 m (10, 20, 30, 39, 49, 66 and 82 ft). Transects extended to a maximum of 4.3 km (2.7 miles) offshore into Lake Michigan. Seventy samples were taken in each region, while in all, 210 samples were taken in the survey area in June 1977. An additional 105 samples per month were taken in August and October 1977. Five replicates were taken at the center of each depth zone in each region. Data for August and October can be found in Appendices 12,13.

Samples were collected using a triplex Ponar grab sampler (Mozley and Chapelsky 1973). Only one chamber of the Ponar (one-third Ponar) was used for a given sample. Once collected, samples were washed through a 0.35 mm mesh net. The concentrated samples were preserved with 4% formalin and returned to the Great Lakes Research Division laboratory for sorting and identification.

Sorting and identification of organisms were performed using a dissecting scope. Specimens unidentifiable at the genus/species level in the initial sorting (Chironomidae, Naididae and Tubificidae) were

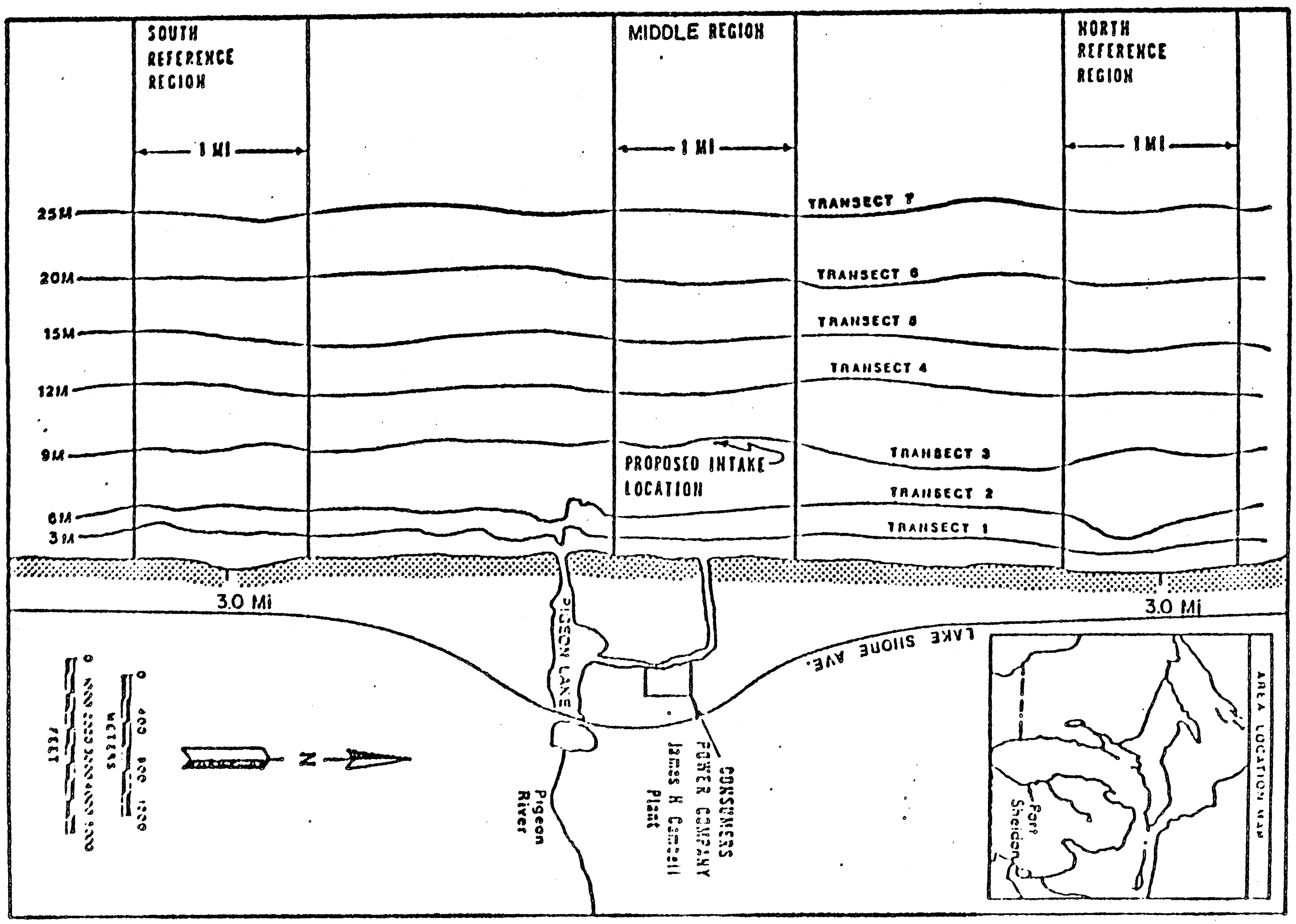


FIG. 6.Benthos sampling design locations in the vicinity of the J.H. Campbell power plant in June 1977.

mounted in lactophenol and identified with a compound scope (400-1000X). Once specimens were identified, data were recorded on permanent data sheets and processed appropriately for statistical analysis. Data were divided into various subsets based on major taxonomic groups and depths of maximum occurrence. Two transformations [log (x+1), square root (x) (Elliot 1971)] were performed on each subset of the data. In each case a histogram and cumulative frequency distribution were constructed and a Lilliefor's test was performed to test normality of the transformed and untransformed data. Transformation of a given subset of data that most closely approximated normality according to the above tests was used in the subsequent analysis of variance (ANOVA).

The ANOVA performed on each subset of the data considered two main effects (depth and region) and interaction effects. The Student-Newman-Keuls multiple comparison technique, *a posteriori* (Sokal and Rohlf 1969), was used in conjunction with the mean square within estimate of the variance to locate significant differences across regions within a given depth and across depths within a given region. Following Mozley (1974) and Johnston (1974), sample replicability and reliability have been analyzed using the least detectable true difference (δ) (Sokal and Rohlf 1969).

Because one replicate of the 210 samples taken in June 1977 was preserved improperly, the sample could not be counted. A correction factor has been applied to the Analysis of Variance results according to Fox (1973). The mean for the transect in that region was entered in place of the missing value. Since only one value was missing, the resulting correction factors for the ANOVAs were negligible.

Benthos samples were collected on 2 June 1977 along six transects in Pigeon Lake which is located in Ottawa County Michigan (Fig. 7). There were four transects (PL1, PL2, PL3, and PL4) located in the western basin of Pigeon Lake, all had two stations located along each transect except PL1 which had only one station. The remaining two transects were located in the eastern basin (PL5 and PLX). Each station was sampled three times (replicates A-C). A total of 39 samples was taken in Pigeon Lake.

Sample sites along a given transect in Pigeon Lake were selected with respect to presence of aquatic macrophytes, visually observed sediment type, lake bottom slope and depth. Sample site selection along a transect was subjective with respect to the characters mentioned above. Description of benthos at a specific station, transect, basin, and the lake as a whole was dependent upon habitat selected. Therefore, while a given sample unit of the lake (station, transect, basin or lake) may be used to describe the area in the vicinity of that unit, it is dependent upon habitat selected.

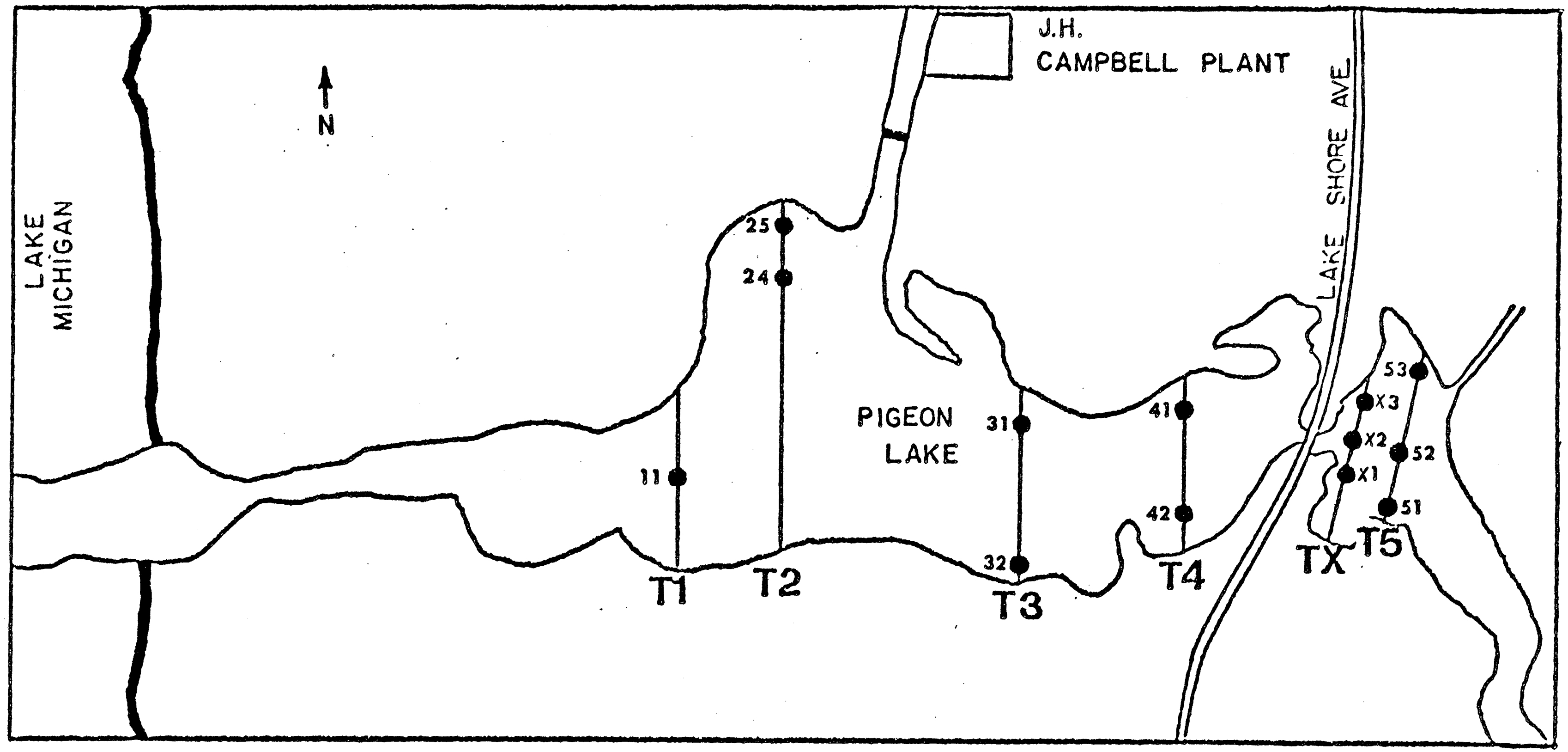


FIG. 7. Transect and station location for benthic macroinvertebrate sample collection in Pigeon Lake near the J. H. Campbell Plant, June 1977 (T = transect).

Benthos samples were collected with a modified Wildco Ponar grab sampler, modified so that the side plates extended up to the central axis that rotates the jaws for cocking and closing. Extension of the side plates prevented loss of material. Upon collection, samples were washed through a 0.35 mm mesh net. The portion retained in the net was stored in 1 quart mason jars and preserved in 4% buffered formalin solution. Samples were returned to the Great Lakes Research Division laboratory in Ann Arbor, Michigan for sorting and identification.

Two methods of sorting were employed. Sugar flotation was used in sorting samples from the following stations with their designated replicates in parentheses: PLX1 (A-C), PLX3 (B), PL52 (A-C) and PL53 (A-C). In the ten samples floated using the sugar solution it was necessary to pick the entire sample residue since it was found that about 6-20% of the total animals present in a sample would not float. As a result, the remaining 29 samples were subsampled when necessary.

In the remaining samples a 1/2-1/32 subsampled portion was extracted from the whole sample. The only exception to this procedure was PLX2 (A-C) where subsampling was not necessary. The entire contents of the subsample were then picked under a dissecting microscope. Because aquatic macrophytes were present in nearly all remaining samples in tangled, clumped masses, subsampling had to be modified from standard techniques. Since aquatic macrophytes could not be effectively subsampled, they were washed and removed from the whole sample before subsampling. The remaining sample residue was then subsampled to an appropriate volume using a Folsom plankton splitter. In order to determine the number of organisms/grab, numbers of animals occurring in the subsampled portion were multiplied by the appropriate inverse of the subsample fraction which ranged from 2-32. Organisms occurring in the macrophytes were sorted separately from the subsample fraction. The number of organisms found in the macrophytes after identification was added to the appropriate taxon in the subsampled portion. Therefore, the number of animals per grab was the addition for any taxon of 1.) the subsample fraction total multiplied by the inverse of the subsample; plus 2.) the number occurring in the macrophyte portion of the sample.

Number of organisms per square meter was obtained by multiplying the number of animals in a taxom in a grab by 19.94. Due to the large number of tubificids present in some samples, tubificid species determination required subsampling. When the number of tubificids exceeded 200 in a sample, a subsample of tubificids was extracted from the whole. Tubificids were placed in a gridded pan and evenly distributed. From a table of random numbers individual squares were selected. Tubificids occurring in the selected square were mounted for identification. This process was repeated until 100 tubificids were mounted. The number for each tubificid species in the sample were

estimated by multiplying each subsampled tubificid species total by the ratio of the total number of tubificids present in the sample divided by the total number of tubificids present in the subsample.

SCUBA OBSERVATIONS

During 9-10 August 1977, daylight underwater observations were made in the vicinity of the J. H. Campbell Plant using SCUBA. A 6 m Boston Whaler served as the support vessel. Seven transects (referred to as dive no. 1-7) were swum during this period (Fig. 8). Photographs were taken periodically at various stations along each transect and a description of physical and biological characteristics of the bottom were recorded on a slate. These observations were later transcribed.

Two transects (dive no. 1 and 3) were swum perpendicular to shore between the 6 and 12 m depth contour (Fig. 6). The first transect was offshore from the discharge canal, the second was offshore from the jetties; each transect covered a distance of approximately 1000 m. At the end of each transect a continuing leg was swum perpendicular to the main transect for distances of 400 and 200 m respectively.

A third transect (dive no. 2) was swum at a reference location 3 km south of the plant. This transect was perpendicular to shore, extending from the 10.5 m to the 6 m contour, a distance of approximately 800 m. A continuing leg was swum south, parallel to shore along the 6 m contour, for a distance of 400 m. An additional three transects (dive no. 4-6) were swum parallel to shore for a distance of 200 m along either the 9 or 12 m contours. One final transect (dive no. 7) was swum 200 m north along the 12 m contour, then shoreward to the 9 m contour, and then 200 m north along the 9 m contour.

Station locations along each transect were selected according to a loosely systematic design with approximately 5 min of swimming time between stations allotted. However, if an unusual feature was noted observations at that station were taken.

Station observations were generally subdivided into the following categories; description of bottom type, presence of organic detritus and biological notes. General between-station observations during swims were also recorded. One diver took photographs, the other diver made and recorded observations. Since visual observations tend to be subjective, the following terms used in this report are defined: few = 1-10, many = 11-50, numerous = 51-100 and abundant = more than 100. Bottom composition was described by one of three relative categories: fine sand, medium sand and coarse sand. "Organic detritus" refers to fragmented pieces of terrestrial vegetation and aquatic debris (dead phytoplankton, mollusc shells, etc). "Floc" refers to the loose

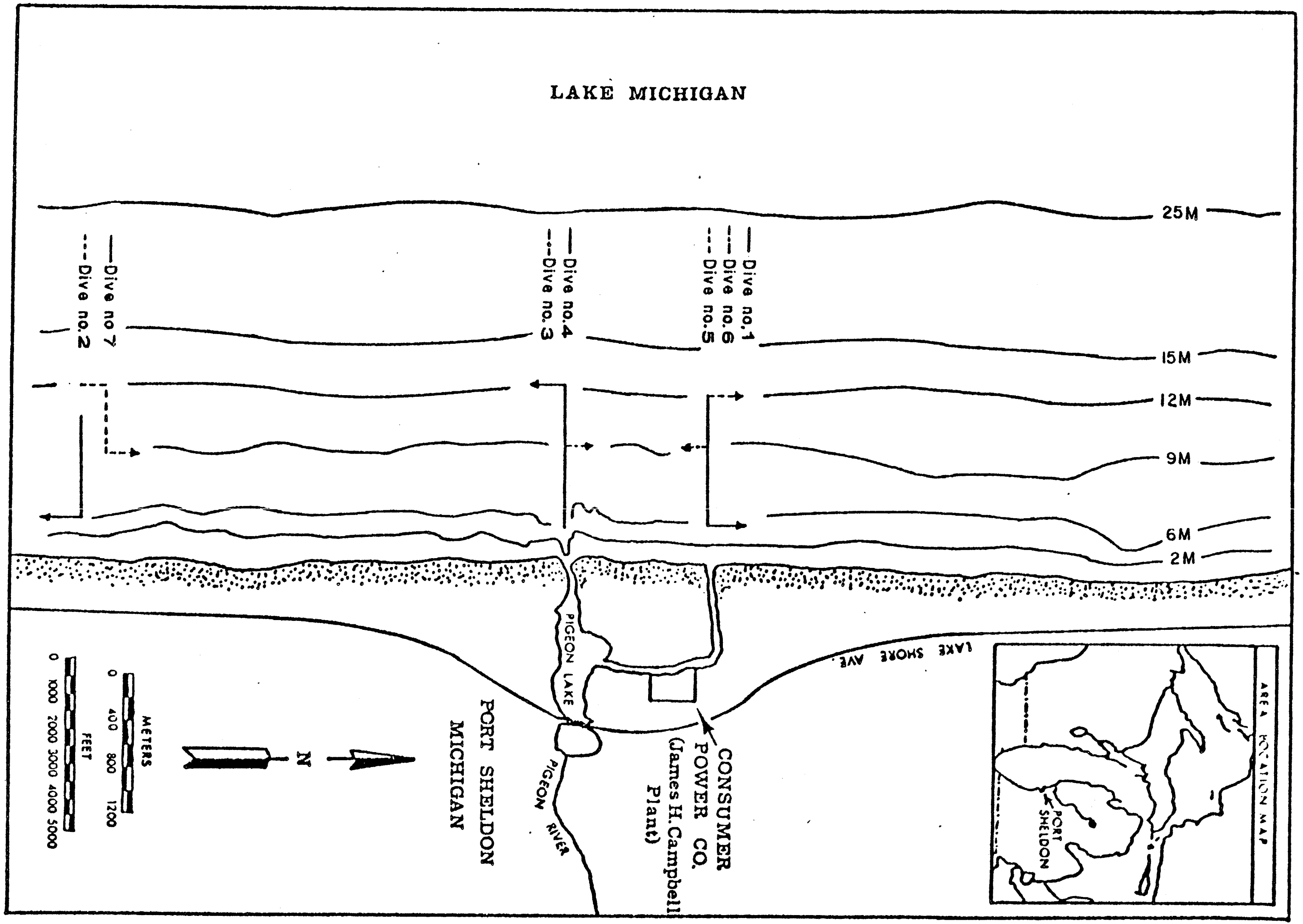


FIG. 8. Schemata of the J. H. Campbell Plant showing Lake Michigan and the eight diving transects swum to monitor bottom topography, 9-10 August 1977.

accumulation of fine particulate material (consisting primarily of sediment, some periphyton and diatomaceous material). Diving observations, which are macroscopic in nature, were limited primarily to demersal organisms and did not include organisms living within the sediment. In addition to the above observations, the boat tender recorded water temperature, transparency (secchi disc), and wave and weather conditions at each station.

RESULTS AND DISCUSSION

STATISTICS

Introduction

Fish populations were sampled using replicate trawls and gill nets at each sampling location and time. All statistical analyses were based upon abundance indices since quantitative estimates of abundance are not possible given the gear employed in this study. Catch per unit effort (CPE) is defined as the total catch in numbers per unit of standard fishing effort. Each sample represented one unit of effort. One unit of trawling effort was defined as a 10 min tow, and one unit of gill net effort was defined as one lift of the net adjusted to a standard 12 hr fishing period. Abundance indices for different gear types are not directly comparable due to different biases of each gear type. The unknown relationships among CPE values derived from different gear require independent analyses of each data set. However, the different gear types provide overlapping and complementary information about fish populations. For example, individual fish which might avoid trawls might be caught by gill nets. Conversely, fish which are too small to be captured in gill nets are likely caught by seines and trawls. Consequently, one must envision the pattern presented by the aggregate of gear types when statistically analyzing the results for each gear.

Design and Analysis Considerations

Statistical analyses were performed for each of the five most abundant species of fish in the field sampling: spottail shiners, alewife, rainbow smelt, yellow perch and trout-perch. Differences in fish abundance between the control and experimental stations were examined using analysis of variance (ANOVA). The experimental designs outlined in the methods section were analyzed as completely crossed factorial models with MONTH, STATION and/or TIME OF DAY as design variables. All factors were considered fixed. The response variable was either number of fish per unit effort or a transform thereof. We transformed raw data by taking the natural logarithm of CPE plus one. The addition of one insured nonnegativity in transformed data. This transform is designed to reduce the variances of data so that the ANOVA assumptions might be more closely met.

The factorial ANOVA models were modified according to species, gear type and presence of zero data. A summary of the models analyzed is given in Table 4. All models included the design variables <u>MONTH</u> and <u>STATION</u>. The <u>MONTH</u> factor was expected to explain a considerable amount of variation attributable to seasonal changes in abundance of inshore

TABLE 4. Summary of experimental designs employed to analyze catch/effort abundance indices for the five most abundant species caught in the vicinity of the Campbell Plant on Lake Michigan from June through December 1977.

Gear	Factors	Levels of Factors	Comments	Species Examined
Trawl	MONTH TIME OF DAY STATION	June - December DAY, NIGHT reference: C (6m-S) discharge: L (6m-N)		Spottail Shiner Alewife Rainbow Smelt Trout-Perch Yellow perch
Bottom Gill Nets	MONTH TIME OF DAY STATION	June, August, September, November DAY, NIGHT reference: C (6m-S) discharge: L (6m-N)		Spottail Shiner Alewife Yellow Perch
Bottom Gill Nets	MONTH STATION	June, July, August, September, November, December reference: C (6m-S) discharge: L (6m-N)	Day samples only; night samples were not analyzed	Alewife Yellow Perch
Surface Gill Nets	MONTH TIME OF DAY STATION	July, September, November DAY, NIGHT reference: C (6m-S) discharge: C (6m-N)	Only alewives were analyzed, catches of other species were too low and highly variable.	Alewife
Surface Gill Nets	MONTH STATION	June, July, August, September, November reference: C (6m-S) discharge: C (6m-N)	Day samples only; night samples were not analyzed. Only alewives were analyzed. Catches of other species were too low and highly variable.	Alewife

fish populations. The <u>STATION</u> factor is supposed to account for differences between the control station C (6 m - s.) and the discharge station L (6 m - n.). <u>TIME-OF-DAY</u> was employed as a design factor for three of the five models examined. This factor was intended to account for diel migrations into and out of the study area. All statistical tests for significance of main effects and interactions were conducted at the 99% probability (α = 0.01) level.

Assumptions for the ANOVA model are: 1) residuals are normally distributed, 2) variances of the population are constant for all partitions of the population and 3) observations are statistically independent. Balanced factorial ANOVAs are robust to the assumptions of normality and homogeneous variances. In other words, moderate departures from these assumptions do not invalidate results of the model. Violation of the independence assumption may have more serious consequences.

Given that these assumptions are met, sensitivity of the ANOVA model to detect the alternate hypothesis can be calculated. In this study we are interested in detecting significant differences between stations. The least detectable true change (LDTC) is the minimum difference in mean abundance levels between stations that can be detected by our experimental design.

The formula for LDTC, as presented by Jude et al. (1975)

$$\delta = s(2/n)^{1/2}(t_{\alpha,\nu} + t_{2(1-P),\nu})$$

where:
- δ = least detectable true change
- s = within cell standard deviation of the ANOVA (i.e. the square root of the mean square error)
- n = number of observations in each of the two groups being compared
- α = significance level
- t = student's t statistic
- ν = degrees of freedom
- P = power (the probability that a true difference will be judged significant by ANOVA).

<u>Methods</u>

BMD8V was used to perform the analyses of variance (Statistical Research Laboratory 1975). The Michigan Interactive Data Analysis System (MIDAS, Fox and Guire 1973) was used for analyses of ANOVA residuals. Residuals, defined as the difference between the cell mean and the actual data value, can be examined to determine how well the ANOVA model meets its assumptions (Draper and Smith 1966). An ALGOL program was written to compute the LDTCs.

TABLE 5. Descriptive statistics used for analyses of variance for sample data collected at stations C (6 m - s.) and L (6 m - n.) near the J. H. Campbell Plant, eastern Lake Michigan, June - December 1977. Sample data are number of fish.

Gear	N	Maximum	$\bar{X}$	Standard Deviation	Percentage of Zero Catch Data
TRAWL (Jun - Dec)					
Spottail shiner	56	46	5.1	9.3	44.6
Alewife	56	683	56.2	133.9	33.9
Rainbow smelt	56	698	71.8	120.1	7.1
Trout-perch	56	29	4.3	7.2	51.8
Yellow perch	56	22	1.9	3.7	44.6
BOTTOM GILL NET (Jul, Aug, Sep, Nov)					
Spottail shiner	32	17	2.5	4.3	59.4
Alewife	32	195	12.0	39.5	56.3
Yellow perch	32	21	4.8	5.5	25.0
BOTTOM GILL NET (Jul-Sep, Nov, Dec)					
Alewife	24	195	15.3	45.1	58.3
Yellow perch	24	21	3.5	6.0	62.5
SURFACE GILL NET (Jul, Sep, Nov)					
Alewife	24	71	17.0	21.8	37.5
SURFACE GILL NET (Jun, Sep, Nov)					
Alewife	20	195	19.0	45.4	55.0

All ANOVA models listed in Table 4 were computed using both raw and log transformed data. Data for all species and gear types were initially screened by calculating mean catch, its variance and percentage of zeroes in the design matrix. Summary statistics for those data sets considered amenable to further statistical analyses are presented in Table 5. Note that the percentage of zero catches for these data usually exceeded 35%. Consequently distribution of values was generally bimodal with modes at zero and near the geometric mean. The transformation did however yield residuals which were slightly

closer to meeting ANOVA assumptions than residuals from raw data values. Unless stated otherwise, future references to abundances in this section will refer to geometric mean abundance derived from log transformed data. Geometric means for various partitions of the data are derived by back transforming cell means from log transformed data. For example if x represents the mean catch for log transformed data, then $x' = e^x$ is the geometric mean catch. Use of log transformed data can yield cell means which are not in the same ranking order as cell means of the original data. If so, the geometric means will also differ in ranking order since the exponential function is monotonic.

The least detectable true change is modified whenever log transformed data are used. LDTC or δ is expressed as the change in the logarithm of fish numbers and not in terms of the actual numbers of fish. Back transforming δ yields e^{δ} which represents the ratio of the mean number of fish per unit effort plus one for control station C as compared with experimental station L. In the transformed coordinate system (i.e. log transformed system) changes will be detectable if $|\bar{x}_C - \bar{x}_L| > d$ where $\bar{x}_C$ and $\bar{x}_L$ refer to the log transformed mean catches at stations C and L respectively. When we return to the original coordinate system differences are detectable whenever:

$$e^{-\delta} > \frac{\bar{x}_L'}{\bar{x}_C'} > e^{\delta}$$

Results

Results for analyses of variance trawl data are summarized in Table 6. Month effects were significant and station effects were insignificant for spottail shiners, rainbow smelt and trout-perch but not for alewife or yellow perch. Night catches generally exceeded day catches for these species. Significance of a particular factor is confounded whenever that factor enters into a significant interaction term. In these cases, the main factor must be interpreted in relation to all significant interactions involving that factor.

Geometric mean abundance is plotted against month for each species in Figure 9. Spottail shiner abundance was high in June, October and December and low in July and August. Alewives were most abundant in October when young-of-the-year were recruited into trawl catches. Peak catches of rainbow smelt in August and September were also related to recruitment of YOY. Trout-perch abundance peaked in July and then declined through December. The geometric mean abundance of yellow perch was greatest in August.

TABLE 6. Summary of analyses of variance for spottail shiners, alewives, rainbow smelt, yellow perch and trout-perch caught in trawls at stations C (6 m - s.) and L (6 m - n.) near the J. H Campbell Plant, eastern Lake Michigan, June through December 1977. S = significant at α = .01, NS = not significant at α = .01.

SOURCE OF VARIATION	DEGREES OF FREEDOM	SPOTTAIL SHINER		ALEWIFE		RAINBOW SMELT		YELLOW PERCH		TROUT-PERCH	
		F. Stat.	Signif.	F. Stat.	Signif.	F. Stat.	Signif.	F. Stat.	Signif.	F. Stat.	Signif.
Main Effects:											
Month (M)	6	31.69	S	16.34	S	31.91	S	12.82	S	10.98	S
Station (S)	1	1.01	NS	0.30	NS	0.92	NS	0.05	NS	0.00	NS
Time (T)	1	98.66	S	0.29	NS	50.38	S	4.33	NS	205.82	S
Interactions:											
MxS	6	4.37	S	0.75	NS	0.55	NS	1.02	NS	1.20	NS
MxT	6	7.96	S	2.44	NS	2.58	NS	2.05	NS	9.95	S
SxT	1	2.82	NS	0.08	NS	0.70	NS	3.25	NS	1.65	NS
MxSxT	6	2.84	NS	1.30	NS	0.72	NS	1.62	NS	0.41	NS
Within Cell Error	28										

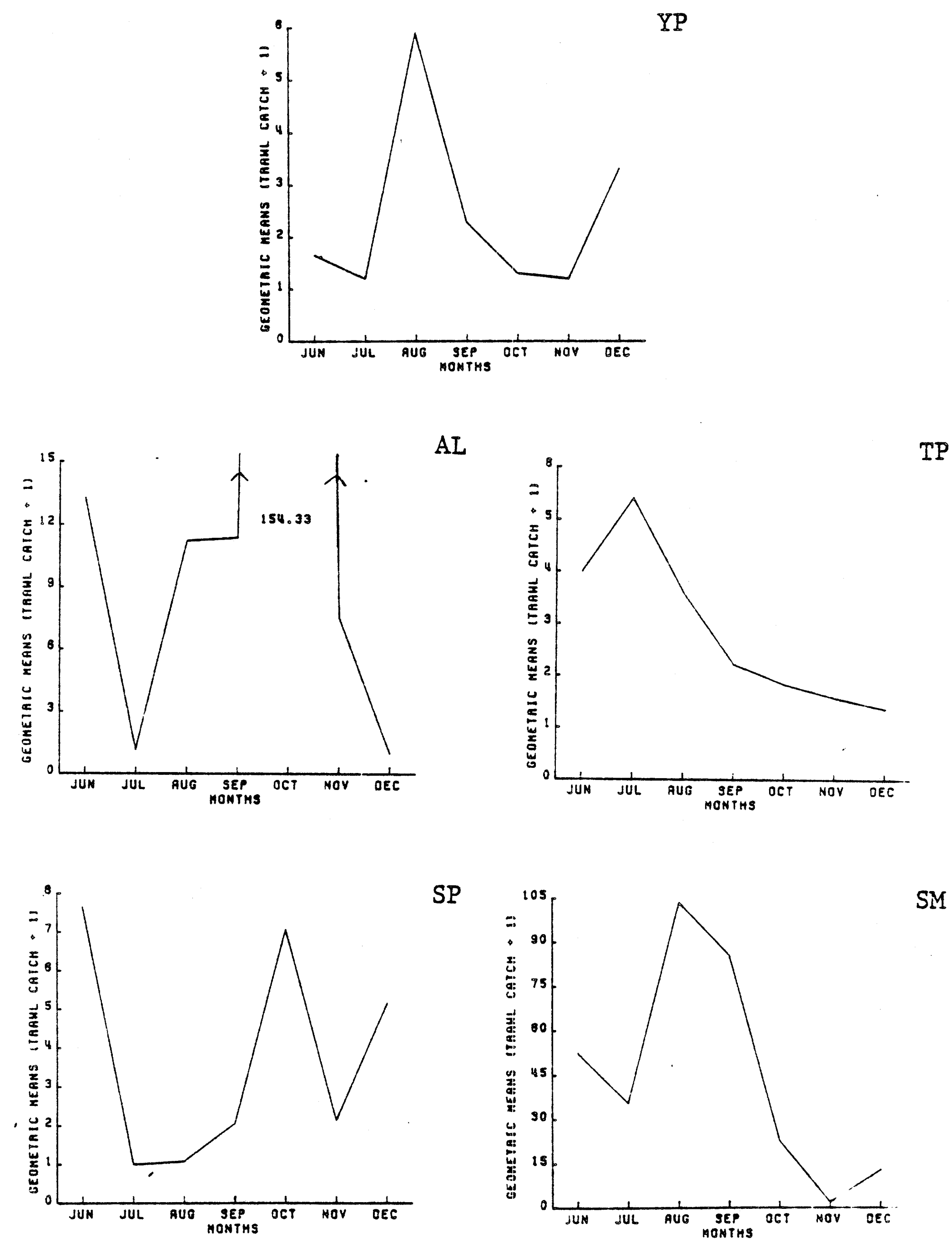


FIG. 9. Geometric mean number (plus one) of spottail shiners, alewives, rainbow smelt, yellow perch and trout-perch caught in trawls at stations C (6 m - s.) and L (6 m - n.) near the J. H. Campbell Plant, eastern Lake Michigan, June through December 1977. YP = Yellow perch, AL = Alewife, TP = Trout-perch, SP = Spottail shiner, SM = Rainbow smelt.

Surprisingly, only three of the possible 20 interaction terms in Table 6 were significant. The MONTH x STATION interaction was significant for spottail shiners; however the F-statistic was very close to the critical value. Figure 10A shows higher abundances at station L than station C in December. The MONTH x TIME-OF-DAY interaction was significant for spottail shiners and trout-perch. For both species the source of the interaction appeared to be the consistently low day catches compared to widely varying night catches over months (Fig. 10B, 10C).

A summary of results of analyses of variance based on bottom gill net data showed monthly differences were significant for each species (Table 7). Spottail shiners and alewives showed similar patterns with abundance peaking in September. Maximum catch/effort for yellow perch occurred in July (Fig. 11). No significant station differences were found for spottail shiners and alewives but yellow perch were significantly more abundant at the control station than in the discharge area. Night catches were significantly higher than day catches for spottail shiners. The MONTH x TIME-OF-DAY interaction term was significant for all species examined. For alewife, CPE was higher in the day than at night in August in contrast to the opposite pattern during July, September and November (Fig. 12A). Yellow perch were generally caught at higher rates at night than in the day except in July (Fig. 13C). The significant MONTH x TIME-OF-DAY interaction for spottail shiners is due to the consistently low daytime catches coupled with widely varying night catches (Fig. 14). The MONTH x STATION x TIME-OF-DAY interaction term was significant for both alewife and yellow perch (Fig. 12B and 13A respectively). Conceptually, a three-way interaction occurs whenever the nature of the interaction between two factors varies with the level of a third factor. Aside from indicating where such differences occur, it is generally difficult to attribute these interactions to causal factors.

Bottom gill net data were also analyzed with a two-way factorial design by considering MONTH and STATION as design variables and eliminating night catches from analyses (Table 8). Only alewife and yellow perch data were analyzed with this model. Once again monthly differences were significant. Peak mean abundances for alewives and yellow perch occurred in July and September respectively (Fig. 15). Neither STATION effects nor the MONTH x STATION interaction were significant for alewives; however both factors were significant for yellow perch. The MONTH x STATION interaction was characterized by higher CPE at station L in June, July, November and December than at station C. In August and September this pattern was reversed (Fig. 15).

Results of analysis of abundance data for alewife caught in surface gill nets suggested that seasonal factors, random error and/or other unrecognized factors accounted for the variation observed. Variation

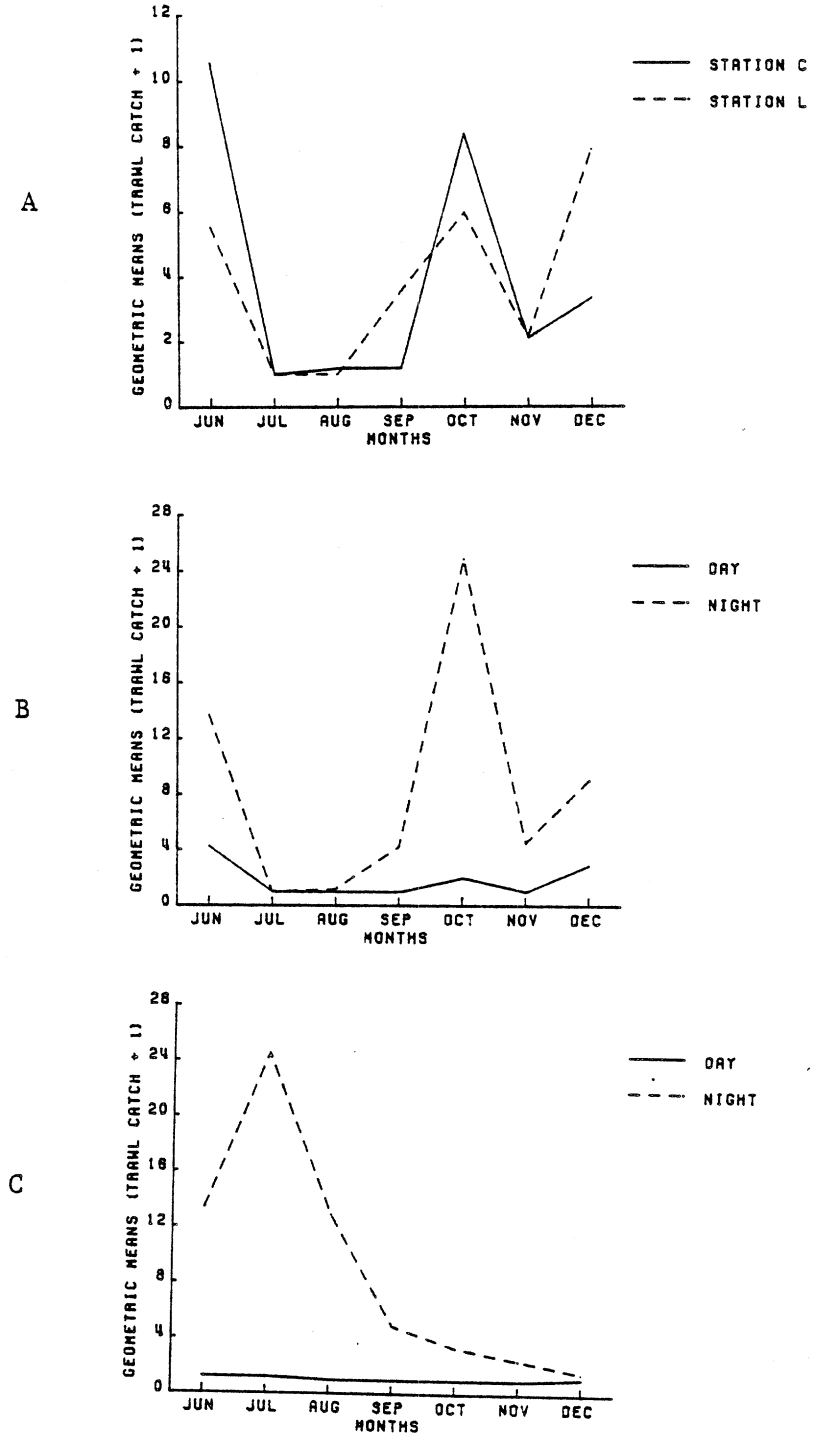


FIG. 10. Geometric mean number (plus one) of spottail shiners and trout-perch caught in trawls at stations C (6 m - s.) and L (6 m - n.) near J. H. Campbell Plant, eastern Lake Michigan, June through December 1977.

A - Spottail shiner: Month-station interaction
B - Spottail shiner: Month-time interaction
C - Trout-perch: Month-time interaction

TABLE 7. . Summary of analyses of variance for spottail shiners, alewives, and yellow perch caught in bottom gill nets at stations C (6 m -s.) and L (6 m -n.) near the J. H. Campbell Plant, eastern Lake Michigan, July, August, September and November 1977. S = significant at α = .01, NS = not significant at α = .01.

SOURCE OF VARIATION	DEGREES OF FREEDOM	SPOTTAIL SHINER F. Stat.	SPOTTAIL SHINER Signif.	ALEWIFE F. Stat.	ALEWIFE Signif.	YELLOW PERCH F. Stat.	YELLOW PERCH Signif.
Main Effects:							
Month (M)	3	25.76	S	17.91	S	6.58	S
Station (S)	1	7.24	NS	5.48	NS	29.51	S
Time (T)	1	84.13	S	8.04	NS	2.99	NS
Interactions:							
MxS	3	1.32	NS	4.35	NS	12.83	S
MxT	3	12.75	S	21.22	S	18.19	S
SxT	1	0.40	NS	0.09	NS	0.82	NS
MxSxT	3	2.43	NS	6.36	S	5.61	S
Within Cell Error	16						

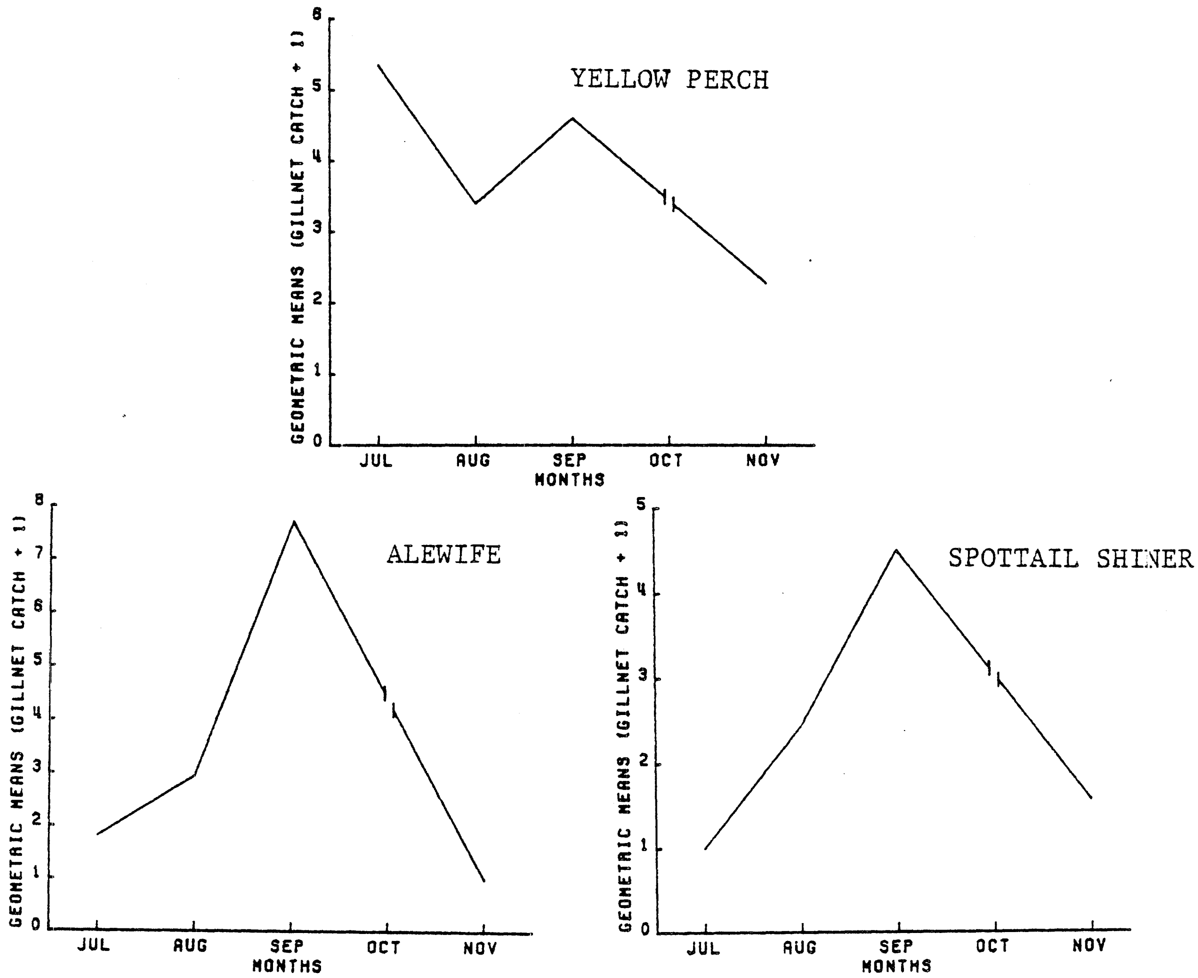


FIG. 11. Geometric mean number (plus one) of spottail shiners, alewives, and yellow perch caught in bottom gill nets at stations C (6 m - s.) and L (6 m - n.) near the J. H. Campbell Plant, eastern Lake Michigan, July, August, September and November 1977.

due to month was significant when MONTH, STATION and TIME were considered (Table 9). However, when the design was reduced to two factors (MONTH and STATION) neither of the factors nor their interaction were significant (Table 10). A plot of monthly geometric means for both designs is given in Figure 16.

Power analyses showing least detectable true differences for each species showed that most LDTC values ranged from 1.3 to 2.0 with a few exceeding 4.0 (Table 11). This implies that the sampling designs employed can probably detect increases in mean abundances from 30 to 100% and decreases from 25 to 50%. Overall, the LDTC's were highest for surface gill nets and lowest for bottom gill nets. Among species, the

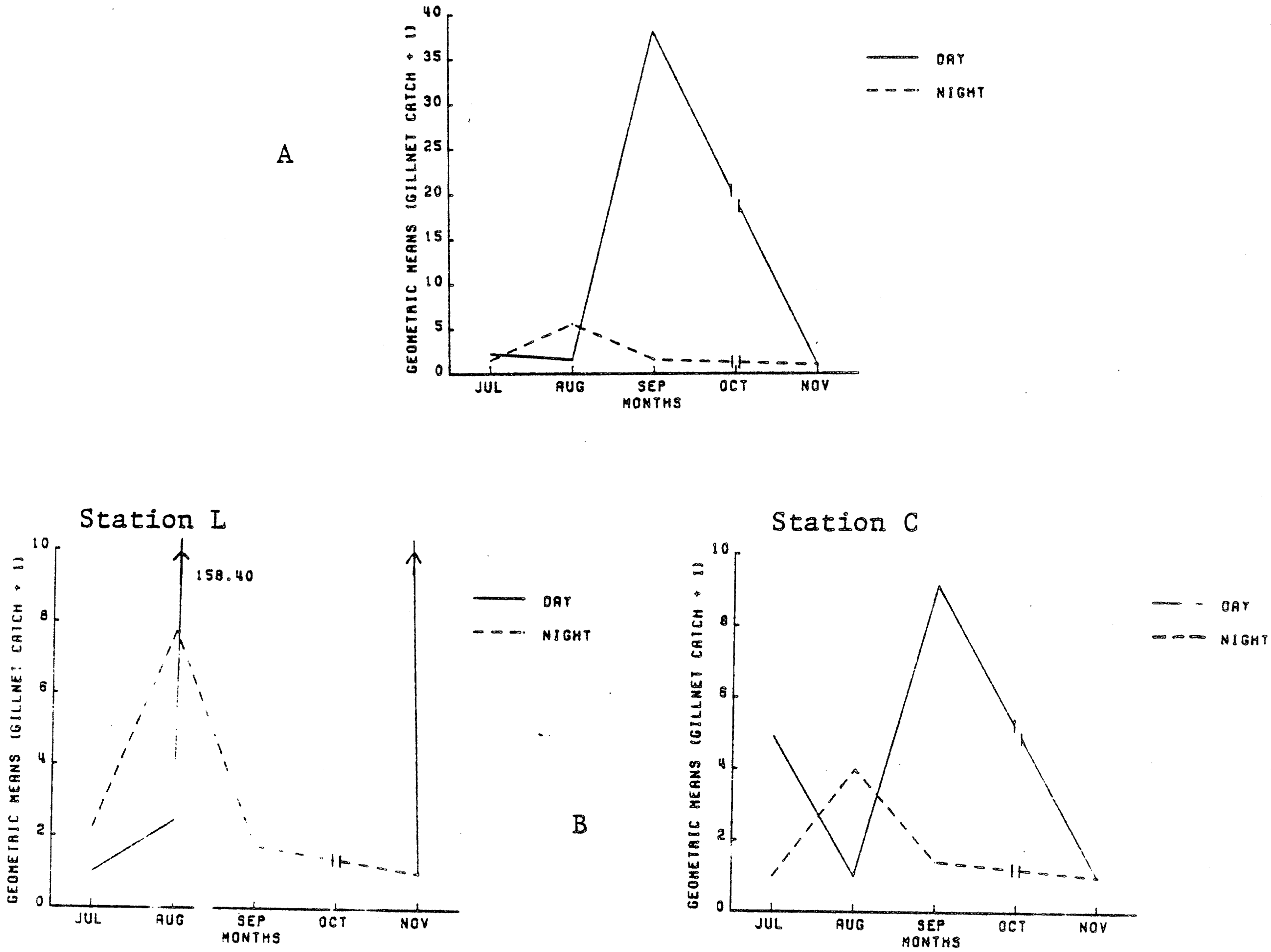


FIG. 12. Geometric mean number (plus one) of alewives caught in bottom gill nets at stations C (6 m - s.) and L (6 m - n.) near J. H. Campbell Plant, eastern Lake Michigan, July, August, September and November 1977.

A - Alewife: Month-time interaction
B - Alewife: Month-station-time interaction

power to detect significant changes was lowest for alewives irrespective of gear used. This may be related to the migrations of alewives and highly variable recruitment of their young. The trawl is probably the best gear for assessing impacts of plant operation. The LDTC's for spottail shiners, yellow perch and trout-perch were very similar. Given that the assumptions of the power analysis have been met, changes exceeding +40% and -30% should be detectable for these species. For rainbow smelt this range is about +62% and - 40%. Changes in mean alewife abundance of less than +133% and greater than -58% could not be detected by the given experimental design. This effect is not a

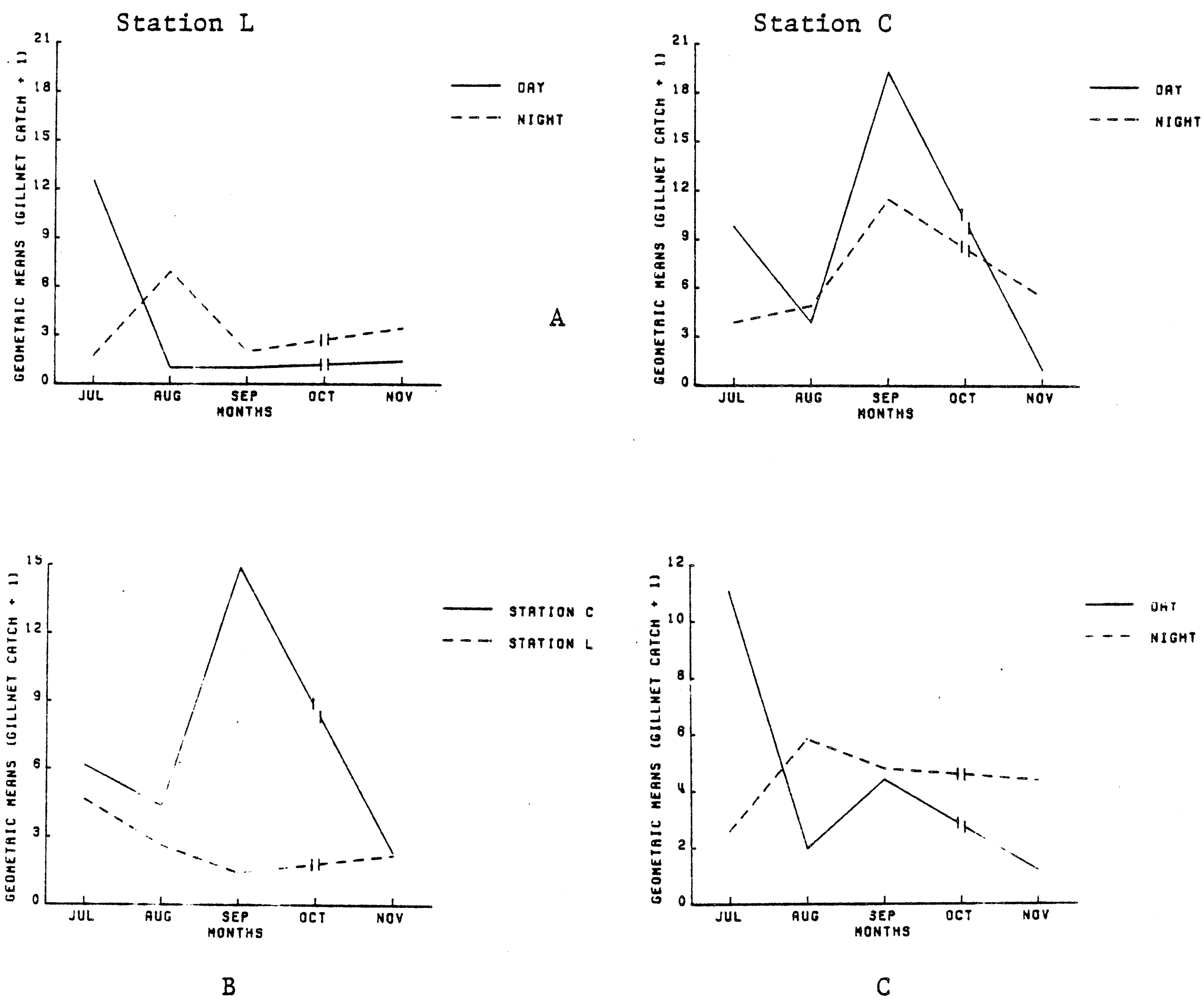


FIG. 13. Geometric mean number (plus one) of yellow perch caught in bottom gill nets at stations C (6 m - s.) and L (6 m - n.) near J. H. Campbell Plant, eastern Lake Michigan, July, August, September and November 1977.

A - Yellow Perch: Month-station-time interaction
B - Yellow Perch: Month-station interaction
C - Yellow Perch: Month-time interaction

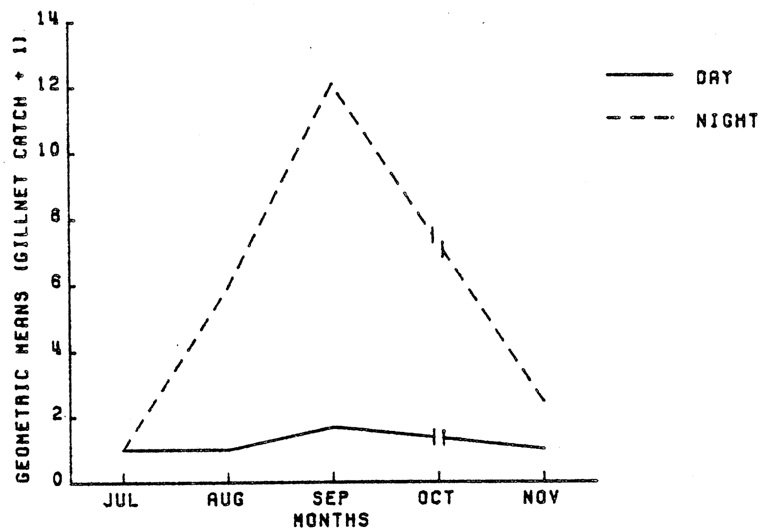


FIG. 14. Geometric mean number (plus one) of spottail shiners caught in bottom gill nets at stations C (6 m - s.) and L (6 m - n.) near the J. H. Campbell Plant, eastern Lake Michigan, July, August, September and November 1977. Month - time interaction for spottail shiners.

reflection on the adequacy of the experimental design, but rather indicates the high variable abundance of alewives within the inshore zone.

Discussion

Future judgements concerning the effect on fish of the current and/or proposed intake and discharge operations at the Campbell Plant must consider the limitations of the data assembled and analyzed herein. Many factors argue forcefully that any sampling program conducted in the inshore waters <u>alone</u>, regardless of intensity or duration, is necessarily more descriptive than comparative or predictive. The dynamic character of inshore fish populations, limited sampling technology, unknown effects of environmental variations and the strong link between spawners and recruits clearly suggest the difficulties associated with assessing the effects of a single factor (i.e. the power plant) on community structure and function. Furthermore, ongoing lakewide biological, chemical and physical processes are likely to supercede and mask potential effects due to operation of the Campbell Plant. For example, species introductions (both accidental and planned) have resulted in a nonequilibrium community structure in which relationships among populations are continually changing (Smith 1968). Similarly, chemical contaminants have altered food sources (e.g. benthos community) and possibly changed the reproductive behavior of some fish such as lake trout (Burdick et al. 1964). Determining the role of the Campbell Plant, acting in

TABLE. 8. Summary of analyses of variance for alewives and yellow perch caught in bottom gill nets during the day only at stations C (6 m -s.) and L (6 m -n.) near the J. H. Campbell Plant, eastern Lake Michigan, June, July, August, September, November and December 1977. S = significant at α = .01, NS = not significant at α = .01.

SOURCE OF VARIATION	DEGREES OF FREEDOM	ALEWIFE		YELLOW PERCH	
		F. Stat.	Signif.	F. Stat.	Signif.
Main Effects:					
Month (M)	5	15.98	S	92.65	S
Station (S)	1	1.58	NS	56.77	S
Interaction:					
MxS	5	4.58	NS	41.55	S
Within Cell Error	12				

concert with numerous other factors, upon the biota of Lake Michigan is a seemingly hopeless task. The ensuing paragraphs address some of these problems and suggest possible alternative analyses.

The dynamic character of inshore fish populations refers not only to the seasonal use of the inshore zone for spawning and recruitment but also the population's ability to respond to imposed stressors. We know a priori that most species are not year-long residents in the inshore zone. Also, we know that some relation exists between the numbers of spawners and recruits observed. In addition, diel, vertical and horizontal movements are known for many species. These factors suggest that catch data might be more effectively modeled with time series techniques rather than analyses of variance. Murarka et al. (1976) have proposed the use of time series techniques for impact analysis which are based upon the methods of Box and Tiao (1965, 1975). Unfortunately, these methods require relatively large data sets extending over several years. For this study, we have less than 1 yr of data.

In view of these constraints, interpretations of statistically significant main effects and interaction terms remain somewhat speculative and tenuous. However, in spite of the complexity and variability in the nearshore system several general patterns emerged. The significant effects due to month are undoubtedly related to the seasonal use of the inshore zone by adult fish for pre-spawning,

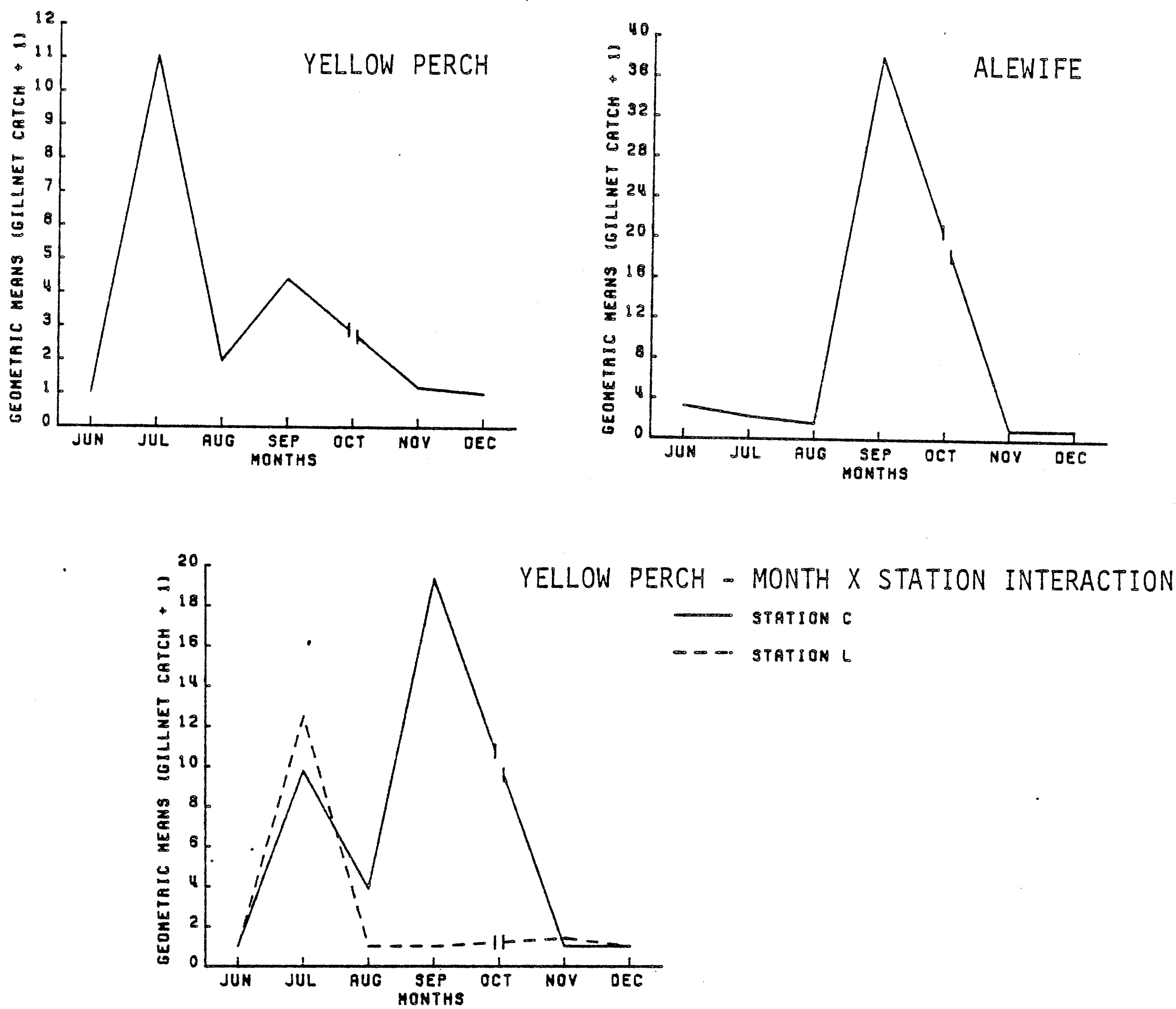


FIG. 15. Geometric mean number (plus one) of alewives and yellow perch caught in bottom gill nets at stations C (6 m - s.) and L (6 m - n.) near the J. H. Campbell Plant, eastern Lake Michigan, day only, July, August, September and November 1977.

spawning and in some cases, post-spawning activites. Subsequent recruitment of young-of-year fish is the other major factor underlying the seasonal effect. Diel differences resulted from three possible causes: 1) horizontal movements within or out of the sampling area, 2) vertical movements within the water column or 3) avoidance of fishing gear during daylight. Station differences may reflect habitat preferences but without corroborating evidence this is difficult to support. Interpretations of significant interations are even more difficult to analyze.

TABLE 9. Summary of analysis of variance for alewives caught in surface gill nets at stations C (6 m - s.) and L (6 m - n.) near the J. H. Campbell Plant, eastern Lake Michigan, July, September and November 1977. S = significant at $\alpha = .01$, NS = not significant at $\alpha = .01$.

SOURCE OF VARIATION	DEGREES OF FREEDOM	ALEWIFE F. Stat.	ALEWIFE Signif.
Main Effects:			
Month (M)	2	14.32	S
Station (S)	1	0.08	NS
Time (T)	1	5.92	NS
Interactions:			
MxS	2	0.36	NS
MxT	2	2.11	NS
SxT	1	0.09	NS
MxSxT	2	0.03	NS
Within Cell Error	12		

TABLE 10. Summary of analysis of variance for alewives caught in surface gill nets during the day only at stations C (6 m - s.) and L (6 m - n.) near the J. H. Campbell Plant, eastern Lake Michigan, June, July, August, September and November 1977. S = significant at $\alpha = .01$, NS = not significant at $\alpha = .01$.

SOURCE OF VARIATION	DEGREES OF FREEDOM	ALEWIFE F. Stat.	ALEWIFE Signif.
Main Effects:			
Month (M)	4	4.45	NS
Station (S)	1	5.27	NS
Interaction:			
MxS	4	3.72	NS
Within Cell Error	10		

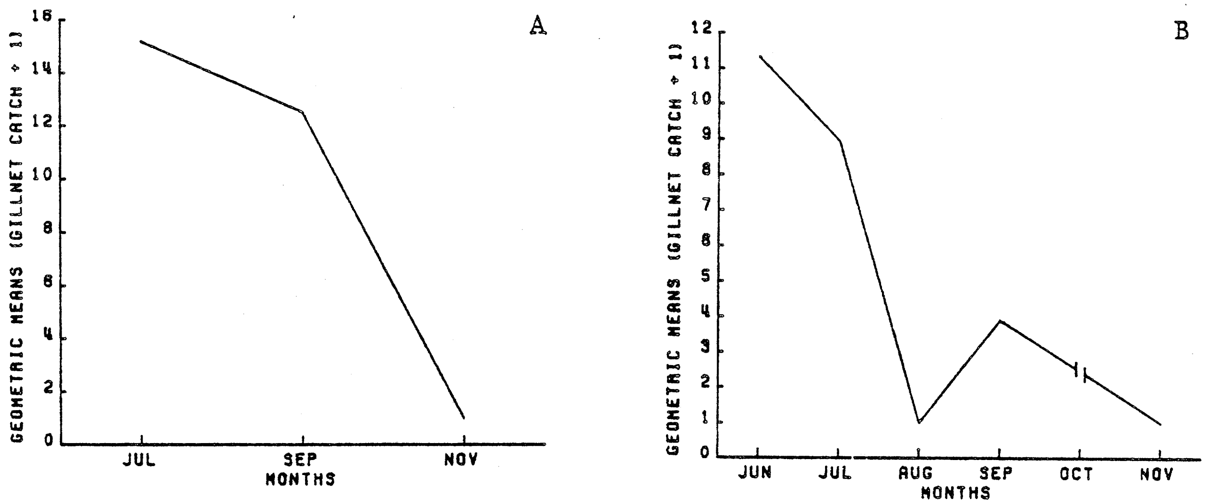


FIG. 16. Geometric mean number (plus one) of alewives caught in surface gill nets at stations C (6 m - s.) and L (6 m - n.) near the J. H. Campbell Plant, eastern Lake Michigan. A = July, September and November. B = June, July, August, September and November, day only.

Statistically significant interaction terms are probably related to changing fish behavior over months (e.g. spatial movements related to temperature) and variable size class structures over time. Each species is considered a single entity, however catch records over a year likely include spawning adults as well as recruited young-of-year. Since behavior, habitat preference, food habits etc. change with age as well as size and time, significant interaction terms are highly probable. Moreover, the underlying mechanism(s) for these effects are unlikely to be attributed to a single factor.

In summary, the analysis of variance models provide some insight into the biology of the species being investigated. ANOVA models should be regarded as an evolving working tool rather than as definitive answer to the questions of power-plant related impacts. Alternative analyses may be employed as additional data become available. Meeting the ANOVA assumptions of normality, homogeneous variances and particularly statistical independence remains the fundamental impediment to their applicability. To our knowledge, there have not been any systematic and unequivocal investigations of alternative analysis methods. Thomas (1977), McCaughran (1977) and Murarka et al. (1976) have addressed these difficult problems but more work is needed.

TABLE 11. Least detectable true changes (LDTC) in geometric mean abundance of spottail shiner, alewife, rainbow smelt, yellow perch and trout-perch at stations C (-m - s.) and L (6m - n.) near the J. H. Campbell Plant. See text for further description.

	P	SPOTTAIL SHINER .90	SPOTTAIL SHINER .95	ALEWIFE .90	ALEWIFE .95	RAINBOW SMELT .90	RAINBOW SMELT .95	YELLOW PERCH .90	YELLOW PERCH .95	TROUT-PERCH .90	TROUT-PERCH .95
Trawl[1]	α = .01	1.39	1.43	2.48	2.71	1.69	1.77	1.44	1.49	1.41	1.45
	.02	1.36	1.40	2.33	2.54	1.63	1.71	1.41	1.46	1.37	1.42
	.05	1.31	1.35	2.13	2.32	1.55	1.62	1.36	1.40	1.33	1.37
	.10	1.28	.132	1.98	2.15	1.48	1.55	1.32	1.36	1.29	1.33
Bottom Gill Net I[2]	α = .01	1.14	1.16	1.42	1.47			1.20	1.22		
	.02	1.13	1.15	1.38	1.43			1.18	1.20		
	.05	1.12	1.13	1.33	1.38			1.16	1.18		
	.10	1.10	1.12	1.30	1.34			1.14	1.16		
Bottom Gill Net II[3]	α = .01			1.79	1.90			1.05	1.06		
	.02			1.72	1.82			1.05	1.05		
	.05			1.61	1.71			1.04	1.05		
	.10			1.54	1.62			1.04	1.04		
Surface Gill Net I[4]	α = .01			4.98	5.80						
	.02			4.41	5.14						
	.05			3.73	4.35						
	.10			3.25	3.79						
Surface Gill Net II[5]	α = .01			5.48	6.46						
	.02			4.81	5.66						
	.05			4.00	4.72						
	.10			3.45	4.06						

1. Trawl data from June - December 1977.
2. Bottom gill net I data for July, August, September and November 1977.
3. Bottom gill net II data includes day only catches from June - September, November and December 1977.
4. Surface gill net I data for July, September and November 1977.
5. Surface gill net II data includes day only catches from June - September and November 1977.

ADULT AND JUVENILE FISH

This section contains adult and juvenile fish data from collections made during 1977 in the vicinity of the Campbell Plant. Due to the complexity of the systems, analyses of data from Lake Michigan and Pigeon Lake were presented separately.

A systematic list of all species collected or sighted during this study (Table 12) showed that 49 species were recorded from Pigeon Lake; 31 were observed from Lake Michigan. Table 12 also includes common and scientific names organized by family, our designated species codes and in which lake each species was caught or observed. Sixty-four species of adult fish representing 21 families were collected from the study area.

An overview of the catch in Lake Michigan is presented in Table 13. Species are ordered by total catch (all gear types combined) and individual species catches are segregated by month. A similar presentation of Pigeon Lake data can be found in Table 14. Alewife was the most frequently captured fish, representing 68.5% numerically of all fish caught in Lake Michigan and 34.3% of the total catch in Pigeon Lake.

Species caught in specific gear types and their catch abundance in Lake Michigan (Tables 15-18) and Pigeon Lake (Tables 19-20) showed that seines were responsible for capturing the most fish in both environments. In Lake Michigan bottom gill nets and surface gill nets were responsible for the capture of 3252 and 844 fish respectively, trawls caught 30541 fish and as noted seine catches were highest with 43971. Alewives comprised numerically the highest percentage of the catch from all four gear types used in Lake Michigan. For Pigeon Lake (Tables 19-20) only two gear types (bottom gill nets and seines) were employed. Seine samples contained 20206 fish of which 35.0% were alewives and 22.5% were spottails. Bottom gill nets only captured 465 fish; most caught (32.5%) were yellow perch followed by bowfin and northern pike (each 14.4%).

For purposes of our analyses, a species was designated major if it represented more than 1% of the total catch for either lake. Lake Michigan major species included alewife, rainbow smelt, spottail shiner, yellow perch and trout-perch. In Pigeon Lake, alewife, spottail shiner, golden shiner, yellow perch, bluntnose minnow, largemouth bass and pumpkinseed were considered major species. Remaining species in the catch for each lake were designated as common when 100 or more specimens were collected and minor if fewer than 100 were taken.

Species were treated differently, depending on abundance in our samples. Discussions of major species included seasonal, spatial and diel distributions of various size and age groups. We attempted to

TABLE 12. Scientific name, common name and abbreviations for all species of fish captured from Campbell Plant study areas from June through December 1977. An X denotes presence in either Lake Michigan or Pigeon Lake. Names assigned according to Bailey et al. 1970.

Scientific and Common Name	Abbreviation	Pigeon Lake	Lake Michigan
Acipenseridae			
Acipenser fulvescens Rafinesque Lake sturgeon	LG		X
Amiidae			
Amia calva Linnaeus Bowfin	BF	X	
Aphredoderidae			
Aphredoderus sayanus (Gilliams) Pirate perch	PR	X	
Atherinidae			
Labidesthes sicculus (Cope) Brook silverside	SV	X	X
Catostomidae			
Carpiodes cyprinus (Lesueur) Quillback	QL	X	
Erimyzon sucetta (Lacépède) Lake chubsucker	ER	X	
Catostomus catostomus (Forster) Longnose sucker	LS		X
Catostomus commersoni (Lacépède) White sucker	WS	X	X
Hypentelium nigricans (Lesueur) Northern hog sucker	HS*	X	
Moxostoma anisurum (Rafinesque) Silver redhorse	MA		X
Moxostoma macrolepidotum (Lesueur) Shorthead redhorse	SR		X
Moxostoma erythrurum (Rafinesque) Golden redhorse	GR	X	
Centrarchidae			
Ambloplites rupestris (Rafinesque) Rock bass	RB	X	
Lepomis gibbosus (Linnaeus) Pumpkinseed	PS	X	X
Lepomis gulosus (Cuvier) Warmouth	WM	X	
Lepomis macrochirus Rafinesque Bluegill	BG	X	X

TABLE 12. (continued).

Scientific and Common Name	Abbreviation	Pigeon Lake	Lake Michigan
Centrarchidae [continued]			
Micropterus dolomieui Lacépède Smallmouth bass	SB	X	
Micropterus salmoides (Lacépède) Largemouth bass	LB	X	
Pomoxis nigromaculatus (Lesueur) Black crappie	BC	X	
Pomoxis annularis Rafinesque White crappie	WC*		
Clupeidae			
Alosa pseudoharengus (Wilson) Alewife	AL	X	X
Dorosoma cepedianum (Lesueur) Gizzard shad	GS	X	X
Cottidae			
Cottus bairdi Girard Mottled sculpin	MS	X	X
Cottus cognatus Richardson Slimy sculpin	SS	X	X
Cyprinidae			
Carassius auratus (Linnaeus) Goldfish	GF	X	
Cyprinus carpio Linnaeus Carp	CP	X	X
Notemigonus crysoleucas (Mitchill) Golden shiner	GL	X	
Notropis atherinoides Rafinesque Emerald shiner	ES	X	X
Notropis dorsalis (Agassiz) Bigmouth shiner	BS	X	
Notropis heterolepsis Eigenmann and Eigenmann Blacknose shiner	NH	X	
Notropis hudsonius (Clinton) Spottail shiner	SP	X	X
Pimephales notatus (Rafinesque) Bluntnose minnow	BM	X	
Pimephales promelas Rafinesque Fathead minnow	PP*		
Rhinichthys cataractae (Valenciennes) Longnose dace	LD	X	X
Semotilus atromaculatus (Mitchill) Creek chub	CR*		

TABLE 12. (continued).

Scientific and Common Name	Abbreviation	Pigeon Lake	Lake Michigan
Cyprinodontidae			
Fundulus diaphanus (Lesueur) Banded killifish	BK	X	
Esocidae			
Esox americanus vermiculatus Lesueur Grass pickerel	GP	X	
Esox lucius Linnaeus Northern pike	NP	X	
Esox lucius x *masquinongy* Tiger muskellunge	TM*		
Gadidae			
Lota lota (Linnaeus) Burbot	BR	X	X
Gasterosteidae			
Pungitius pungitius (Linnaeus) Ninespine stickleback	NS	X	X
Ictaluridae			
Ictalurus melas (Rafinesque) Black bullhead	BB	X	
Ictalurus natalis (Lesueur) Yellow bullhead	YP	X	
Ictalurus nebulosus (Lesueur) Brown bullhead	BN	X	
Ictalurus punctatus (Rafinesque) Channel catfish	CC	X	X
Noturus gyrinus (Mitchill) Tadpole madtom	MT	X	
Lepisosteidae			
Lepisosteus oculatus (Winchell) Spotted gar	SG*		
Lepisosteus osseus (Linnaeus) Longnose gar	LR*		
Osmeridae			
Osmerus mordax (Mitchill) Rainbow smelt	SM	X	X

TABLE 12. (continued).

Scientific and Common Name	Abbreviation	Pigeon Lake	Lake Michigan
Percidae			
Stizostedion vitreum vitreum (Mitchill) Walleye	WL	X**	
Etheostoma nigrum Rafinesque Johnny darter	JD	X	X
Perca flavescens (Mitchill) Yellow perch	YP	X	X
Percina caprodes (Rafinesque) Logperch	LP*		
Percopsidae			
Percopsis omiscomaycus (Walbaum) Trout-perch	TP	X	X
Petromyzontidae			
Ichthyomyzon castaneus Girard Chestnut lamprey	CL*		
Petromyzon marinus Linnaeus Sea lamprey	SL*		
Salmonidae			
Coregonus artedii Lesueur Cisco or lake herring	LH	X	
Coregonus clupeaformis (Mitchill) Lake whitefish	LW		X
Oncorhynchus kisutch (Walbaum) Coho salmon	CM	X	X
Oncorhynchus tshawytscha (Walbaum) Chinook salmon	CH	X**	X
Prosopium cylindraceum (Pallas) Round whitefish	RW		X
Salmo gairdneri Richardson Rainbow trout	RT	X	X
Salmo trutta Linnaeus Brown trout	BT	X*	X
Salvelinus namaycush (Walbaum) Lake trout	LT	X	X
Sciaenidae			
Aplodinotus grunniens Rafinesque Freshwater drum	FD*	X	

* Not observed in 1977 standard sampling series.

** Based on observation made while electroshocking, 1977.

TABLE 13. Summary of all fish species caught by all gear types in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, June-December, 1977.

Species	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	%OF TOTAL
Alewife	2198	5850	13680	16314	9413	6409	0	53864	68.522
Rainbow smelt	1065	554	7418	2706	353	70	732	12898	16.408
Spottail	559	1207	1444	4021	366	88	198	7883	10.028
Yellow perch	92	147	448	463	7	43	54	1254	1.595
Trout-perch	326	221	129	133	36	43	5	893	1.136
Unidentified coregonid	74	46	4	38	234	61	4	461	0.586
Johnny darter	116	13	17	73	68	10	1	298	0.379
White sucker	3	51	151	84	0	4	1	294	0.374
Lake trout	4	56	1	120	1	18	1	201	0.256
Gizzard shad	0	3	14	50	13	94	0	174	0.221
Ninespine stickleback	87	16	11	14	3	2	0	133	0.169
Coho salmon	47	0	0	3	0	4	0	54	0.069
Brown trout	11	6	3	15	0	14	0	49	0.062
Slimy sculpin	12	5	0	0	3	1	23	44	0.056
Longnose sucker	0	16	13	6	0	1	0	36	0.046
Silver redhorse	0	6	2	3	0	1	0	12	0.015
Lake whitefish	7	2	0	1	0	0	0	10	0.013
Rainbow trout	0	0	0	1	3	4	0	8	0.010
Round whitefish	0	1	0	3	1	2	1	8	0.010
Carp	0	4	2	1	0	0	0	7	0.009
Channel catfish	0	0	6	0	0	0	0	6	0.008
Chinook salmon	1	0	0	1	0	2	0	4	0.005
Bluegill	0	0	0	0	4	0	0	4	0.005
Mottled sculpin	4	0	0	0	0	0	0	4	0.005
Longnose dace	0	0	0	0	1	2	0	3	0.004
Silverside	0	0	0	0	1	0	0	1	0.001
Shorthead redhorse	0	0	1	0	0	0	0	1	0.001
Emerald shiner	0	0	1	0	0	0	0	1	0.001
Lake sturgeon	0	1	0	0	0	0	0	1	0.001
Pumpkinseed	0	0	0	0	1	0	0	1	0.001
Burbot	0	0	0	0	0	0	1	1	0.001
	4606	8205	23345	24050	10508	6873	1021	78608	

TABLE 14. Summary of all fish species caught by all gear types in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, June-December 1977.

	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	%OF TOTAL
Alewife	15	6758	183	133	4	0	1	7094	34.319
Spottail	3	1557	527	2333	118	9	0	4547	21.997
Golden shiner	184	1648	630	151	0	2	0	2615	12.651
Yellow perch	357	941	398	387	146	224	6	2459	11.896
Bluntnose minnow	174	582	653	110	5	36	0	1560	7.547
Largemouth bass	273	174	136	107	16	54	0	760	3.677
Pumpkinseed	31	39	54	25	38	45	0	232	1.122
Black crappie	3	85	37	34	9	6	9	183	0.885
Bluegill	4	9	41	58	33	33	0	178	0.861
Rock bass	32	77	46	9	6	3	0	173	0.837
Silverside	9	24	31	79	10	5	0	158	0.764
Brown bullhead	7	48	25	6	19	15	0	120	0.581
Northern pike	14	17	16	12	7	29	18	113	0.547
Johnny darter	12	34	20	7	13	23	0	109	0.527
Bowfin	4	1	9	13	17	9	17	70	0.339
Tadpole madtom	10	10	1	14	8	12	0	55	0.266
Grass pickeral	7	9	14	7	6	7	0	50	0.242
Lake chubsucker	18	9	3	3	6	7	0	46	0.223
Yellow bullhead	3	1	15	0	13	3	0	35	0.169
White sucker	0	4	2	2	5	2	3	18	0.087
Black bullhead	1	0	3	9	0	4	0	17	0.082
Carp	0	3	3	2	2	1	4	15	0.073
Slimy sculpin	0	0	1	1	5	2	0	9	0.044
Rainbow smelt	0	4	1	1	0	1	0	7	0.034
Gizzard shad	0	1	2	4	0	0	0	7	0.034
Warmouth	1	3	0	2	0	0	0	6	0.029
Smallmouth bass	3	0	0	0	0	2	0	5	0.024
Trout-perch	0	0	0	0	0	2	2	4	0.019
Emerald shiner	0	1	1	1	0	0	0	3	0.015
Banded killifish	0	0	0	0	0	2	0	2	0.010
Rainbow trout	0	0	0	0	0	2	0	2	0.010
Goldfish	0	0	2	0	0	0	0	2	0.010
Golden redhorse	0	0	0	0	1	0	0	1	0.005
Bigmouth shiner	1	0	0	0	0	0	0	1	0.005
Cisco	0	0	0	1	0	0	0	1	0.005
Coho salmon	0	0	0	0	0	1	0	1	0.005
Blacknose shiner	0	0	0	0	1	0	0	1	0.005
Lake trout	1	0	0	0	0	0	0	1	0.005
Pirate perch	0	0	0	0	1	0	0	1	0.005
Burbot	0	0	0	0	0	0	1	1	0.005
Longnose dace	0	0	0	1	0	0	0	1	0.005
Quillback	0	0	0	0	0	0	1	1	0.005
Mottled sculpin	0	0	0	0	0	1	0	1	0.005
Channel catfish	0	0	0	0	0	1	0	1	0.005
Ninespine stickleback	1	0	0	0	0	0	0	1	0.005
	1169	12039	2854	3512	489	546	62	20667	

explain the results of the study on the basis of biological and physical considerations and compared our findings with those available in the literature. Gonad data were used to identify spawning periods and explain distribution and were only presented for major and common species. Numbers presented in the table reflected the number of fish actually processed. Due to our subsampling procedures, gonad data could be biased since the most numerous size intervals were underrepresented. For each major species data concerning the water temperatures where a particular size fish was most often caught are presented. Using length-frequency histograms, we were able to separate YOY from adults and compare each group's distribution and behavior. Biological aspects related to temperature preference, predation and feeding habits were

TABLE 15. Summary of all fish species caught by bottom gill nets in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, June-December 1977.

	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	%OF TOTAL
Alewife	67	327	325	435	0	1	0	1155	35.517
Yellow perch	58	111	368	146	1	37	0	721	22.171
Spottail shiner	26	40	144	349	0	31	0	590	18.143
White sucker	2	48	150	82	0	4	1	287	8.825
Lake trout	2	42	1	101	0	18	0	164	5.043
Gizzard shad	0	0	12	3	0	71	0	86	2.645
Rainbow smelt	0	3	7	53	0	0	0	63	1.937
Unidentified coregonid	34	16	0	5	0	0	0	55	1.691
Longnose sucker	0	15	13	6	0	0	0	34	1.046
Trout-perch	0	2	8	3	0	21	0	34	1.046
Brown trout	2	3	3	11	0	10	0	29	0.892
Silver redhorse	0	2	2	3	0	1	0	8	0.246
Channel catfish	0	0	6	0	0	0	0	6	0.185
Round whitefish	0	1	0	3	0	2	0	6	0.185
Coho salmon	0	0	0	1	0	4	0	5	0.154
Rainbow trout	0	0	0	0	0	4	0	4	0.123
Lake whitefish	0	1	0	1	0	0	0	2	0.062
Carp	0	0	2	0	0	0	0	2	0.062
Shorthead redhorse	0	0	1	0	0	0	0	1	0.031
	191	611	1042	1202	1	204	1	3252	

TABLE 16. Summary of all fish species caught by surface gill nets in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, June-December 1977.

	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	%OF TOTAL
Alewife	278	251	0	205	0	0	0	734	86.967
Rainbow smelt	0	1	0	34	0	0	0	35	4.147
Lake trout	0	12	0	17	0	0	0	29	3.436
Gizzard shad	0	0	0	0	0	19	0	19	2.251
Brown trout	0	2	0	4	0	4	0	10	1.185
Unidentified coregonid	0	7	0	0	0	0	0	7	0.829
White sucker	0	1	0	2	0	0	0	3	0.355
Chinook salmon	0	0	0	1	0	2	0	3	0.355
Coho salmon	0	0	0	2	0	0	0	2	0.237
Spottail shiner	0	1	0	0	0	0	0	1	0.118
Longnose sucker	0	1	0	0	0	0	0	1	0.118
	278	276	0	265	0	25	0	844	

TABLE 17. Summary of all fish species caught by trawls in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, June - December 1977.

	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	%OF TOTAL
Alewife	743	195	2137	794	6557	4765	0	15191	49.740
Rainbow smelt	1046	545	7395	2590	348	69	732	12725	41.665
Trout-perch	322	219	119	130	36	22	5	853	2.793
Spottail shiner	98	0	2	38	314	33	198	683	2.236
Unidentified coregonid	40	23	4	26	234	61	4	392	1.284
Johnny darter	116	13	17	73	68	9	1	297	0.972
Yellow perch	34	5	66	32	6	4	54	201	0.658
Ninespine stickleback	86	16	11	14	3	2	0	132	0.432
Slimy sculpin	12	5	0	0	3	1	23	44	0.144
Lake whitefish	7	1	0	0	0	0	0	8	0.026
Lake trout	2	2	0	0	0	0	1	5	0.016
Mottled sculpin	4	0	0	0	0	0	0	4	0.013
Round whitefish	0	0	0	0	1	0	1	2	0.007
White sucker	1	0	1	0	0	0	0	2	0.007
Burbot	0	0	0	0	0	0	1	1	0.003
Longnose sucker	0	0	0	0	0	1	0	1	0.003
	2511	1024	9752	3697	7570	4967	1020	30541	

TABLE 18. Summary of all fish species caught by seines in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, June - December 1977.

Species	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	%OF TOTAL
Alewife	1110	5077	11218	14880	2856	1643	0	36784	83.655
Spottail	435	1166	1298	3634	52	24	0	6609	15.030
Yellow perch	0	31	14	285	0	2	0	332	0.755
Rainbow smelt	19	5	16	29	5	1	0	75	0.171
Gizzard shad	0	3	2	47	13	4	0	69	0.157
Coho salmon	47	0	0	0	0	0	0	47	0.107
Brown Trout	9	1	0	0	0	0	0	10	0.023
Unidentified coregonid	0	0	0	7	0	0	0	7	0.016
Trout-perch	4	0	2	0	0	0	0	6	0.014
Carp	0	4	0	1	0	0	0	5	0.011
Bluegill	0	0	0	0	4	0	0	4	0.009
Rainbow trout	0	0	0	1	3	0	0	4	0.009
Silver redhorse	0	4	0	0	0	0	0	4	0.009
Longnose dace	0	0	0	0	1	2	0	3	0.007
Lake trout	0	0	0	2	1	0	0	3	0.007
White sucker	0	2	0	0	0	0	0	2	0.005
Silverside	0	0	0	0	1	0	0	1	0.002
Johnny darter	0	0	0	0	0	1	0	1	0.002
Lake sturgeon	0	1	0	0	0	0	0	1	0.002
Emerald shiner	0	0	1	0	0	0	0	1	0.002
Pumpkinseed	0	0	0	0	1	0	0	1	0.002
Chinook salmon	1	0	0	0	0	0	0	1	0.002
Ninespine stickleback	1	0	0	0	0	0	0	1	0.002
	1626	6294	12551	18886	2937	1677	0	43971	

TABLE 19. Summary of all fish species caught by bottom gill nets in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, June - December 1977.

Species	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	%OF TOTAL
Yellow perch	50	13	35	21	9	17	6	151	32.473
Bowfin	4	1	6	13	17	9	17	67	14.409
Northern pike	2	3	11	7	7	19	18	67	14.409
Brown bullhead	6	1	2	1	9	13	0	32	6.882
Alewife	12	1	8	6	3	0	1	31	6.667
Black crappie	1	3	2	4	5	1	9	25	5.376
White sucker	0	4	2	2	4	1	3	16	3.441
Yellow bullhead	2	1	0	0	6	2	0	11	2.366
Carp	0	1	1	2	2	1	4	11	2.366
Golden shiner	0	1	3	7	0	0	0	11	2.366
Gizzard shad	0	1	2	4	0	0	0	7	1.505
Largemouth bass	0	0	3	3	0	0	0	6	1.290
Spottail shiner	0	3	0	0	2	0	0	5	1.075
Black bullhead	0	0	3	2	0	0	0	5	1.075
Trout-perch	0	0	0	0	0	2	2	4	0.860
Pumpkinseed	0	0	0	2	0	2	0	4	0.860
Rainbow trout	0	0	0	0	0	2	0	2	0.430
Smallmouth bass	0	0	0	0	0	2	0	2	0.430
Warmouth	0	0	0	1	0	0	0	1	0.215
Lake trout	1	0	0	0	0	0	0	1	0.215
Burbot	0	0	0	0	0	0	1	1	0.215
Cisco	1	0	0	0	0	0	0	1	0.215
Grass pickerel	0	0	1	0	0	0	0	1	0.215
Quillback	0	0	0	0	0	0	1	1	0.215
Golden redhorse	0	0	0	0	1	0	0	1	0.215
Coho salmon	0	0	0	0	0	1	0	1	0.215
	79	33	79	75	65	72	62	465	

TABLE 20. Summary of all fish species caught by seines in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, June - December 1977.

Species	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	%OF TOTAL
Alewife	3	6757	175	127	1	0	0	7063	34.955
Spottail	3	1554	527	2333	116	9	0	4542	22.478
Golden shiner	184	1647	627	144	0	2	0	2604	12.887
Yellow perch	307	928	363	366	137	207	0	2308	11.422
Bluntnose minnow	174	582	653	110	5	36	0	1560	7.720
Largemouth bass	273	174	133	104	16	54	0	754	3.732
Pumpkinseed	31	39	54	23	38	43	0	228	1.128
Bluegill	4	9	41	58	33	33	0	178	0.881
Rock bass	32	77	46	9	6	3	0	173	0.856
Silverside	9	24	31	79	10	5	0	158	0.782
Black crappie	2	82	35	30	4	5	0	158	0.782
Johnny darter	12	34	20	7	13	23	0	109	0.539
Brown bullhead	1	47	23	5	10	2	0	88	0.436
Tadpole madtom	10	10	1	14	8	12	0	55	0.272
Grass pickerel	7	9	13	7	6	7	0	49	0.243
Lake chubsucker	18	9	3	3	6	7	0	46	0.228
Northern pike	12	14	5	5	0	10	0	46	0.228
Yellow Bullhead	1	0	15	0	7	1	0	24	0.119
Black bullhead	1	0	0	7	0	4	0	12	0.059
Slimy sculpin	0	0	1	1	5	2	0	9	0.045
Rainbow smelt	0	4	1	1	0	1	0	7	0.035
Warmouth	1	3	0	1	0	0	0	5	0.025
Carp	0	0	0	0	0	3	0	3	0.015
Smallmouth bass	3	0	0	0	0	0	0	3	0.015
Bowfin	0	0	3	0	0	0	0	3	0.015
Emerald shiner	0	1	1	1	0	0	0	3	0.015
Banded killifish	0	0	0	0	0	2	0	2	0.010
Goldfish	0	0	2	0	0	0	0	2	0.010
White sucker	0	0	0	0	1	1	0	2	0.010
Bigmouth shiner	1	0	0	0	0	0	0	1	0.005
Blacknose shiner	0	0	0	0	1	0	0	1	0.005
Ninespine stickleback	1	0	0	0	0	0	0	1	0.005
Pirate perch	0	0	0	0	1	0	0	1	0.005
Mottled sculpin	0	0	0	0	0	1	0	1	0.005
Channel catfish	0	0	0	0	0	1	0	1	0.005
Longnose dace	0	0	0	1	0	0	0	1	0.005
	090	12006	2775	3437	424	474	0	20206	

discussed when pertinent. Statistical analyses were done for major species in Lake Michigan to determine differences between months, stations C (6 m - s.) and L (6 m - n.) and time of day (see STATISTICS). Common and minor species discussions include the size range, spatial and diel behavior patterns, spawning times and catch-temperatures when enough data were available.

Several appendices contain data supplementary to the data presented in this section. Limnological and weather data collected during each sampling period are presented by gear type in Appendices 1-3. Length-frequency tables for all species caught during 1977 are presented by lake and month (Appendix 4), while Appendix 5 includes length-frequency tables for major species by gear type, month and lake.

Major species

Alewife--

Introduction -- The alewife is indigenous to the Atlantic Coast and was unknown in Lake Michigan prior to 1949 (Brown 1972). Its arrival in the Great Lakes has been attributed to passage through the Erie Canal (Smith 1968). The numbers of alewives in Lake Michigan increased dramatically during the 1960's until 1967 when a lakewide mass mortality decimated the population (Brown 1972). The cause of the dieoff remains undetermined, although many theories have been offered (Smith 1968). The alewife remains the most abundant species in Lake Michigan. Alewives are a major prey resource for the large numbers of salmonids in Lake Michigan (Wells and McLain 1973). Commercially, alewives are important in fish meal and pet food production (Scott and Crossman 1973).

Alewives were the most abundant species captured by our sampling gear in both Lake Michigan and Pigeon Lake. This species accounted for 68% of the total catch by number in Lake Michigan (Table 13) and 34% of the total in Pigeon Lake (Table 14). In Lake Michigan, large seine catches of YOY alewives constituted most of the alewife catch (69%) (Appendix 4 and Table 18). Trawls contributed 28% of the total (Appendix 4 and Table 17) with 91% of the trawl catches containing YOY. The remainder of the alewives collected in Lake Michigan were caught in bottom gill nets (2%) (Appendix 4 and Table 15) and surface gill nets (1%) (Table 16). Most of the gill net catch was comprised of adults. Virtually all alewives caught in Pigeon Lake were YOY, except for a few adults caught in seines and bottom gill nets.

According to Reigle (1969) and Wells (1968) most alewives in Lake Michigan concentrate in deep water from January until mid-April. During May a massive shoreward migration occurs and alewives can be found over many depths. This migration occurs first at the southern end of the lake and proceeds northward. Spawning begins around mid-May in the southern end of Lake Michigan.

Seasonal Distribution --

June -- In Lake Michigan more adult alewives were caught during June than any other month (Appendix 4). Gonad data indicated that some spawning had occurred by the first week of June (Table 21) based on the occurrence of spent alewives. Most fish caught in the study area had moderately or well developed gonads. During the day the largest trawl catches occurred at station C (6 m - s.) and station L (6 m - n.); 297 and 334 respectively (Figs. 17 and 18). The only other day trawl catch containing alewives was taken at station H (21 m - s.). No trawling was done any closer to shore than 6 m, but higher concentrations would be expected there based on gill net data. Relatively few alewives

TABLE 21. . Monthly gonad conditions of alewives caught in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development	25	52	96	143	11		
	Mod. development	54	46	15	3	3	1	
	Well developed	88	5					
	Ripe-running	2						
	Spent	25	12	8	10			
Females	Slight development	6	30	47	110	4		
	Mod. development	32	45	14	4			
	Well developed	108	35	2				
	Ripe-running		1					
	Spent	40	19	5	23			
	Absorbing							
Immature		71	227	400	647	778	500	
Unable to distinguish		6	1	2	2			

were caught in bottom gill nets, but the highest catch (36) occurred at station A (1.5 m - s.) and declined with greater depth (Figs. 19 and 20). Despite some problems encountered when setting surface gill nets in June these nets caught large numbers of alewives (278) at station L (6 m - n.), but none at stations C (6 m - s.), D (9 m - s.), or E (13 m - s.) (Fig. 21 and Table 22). Based on gill net and trawl data, adult alewives seemed to be concentrated between 3 and 6 m during the day.

While bottom gill net and trawl catches of alewife at station C (6 m - s.) and L (6 m - n.) were similar, surface gill net catches were not. Considerable numbers were caught at station L (6 m - n.) but none were caught at station C (6 m - s.) (Fig. 21). This could have been due to water temperature as surface water at station L (6 m - n.) was 12.0 C, 3.5 C warmer than station C (6 m - s.). The lake was calm that day and the warmer discharge water, being less dense than the lake water, was creating localized stratification. This difference may also have been due to problems encountered in setting srface gill nets during the first month of use.

There are several possibilities why trawls were so effective in catching alewives compared to bottom gill nets. The most plausible

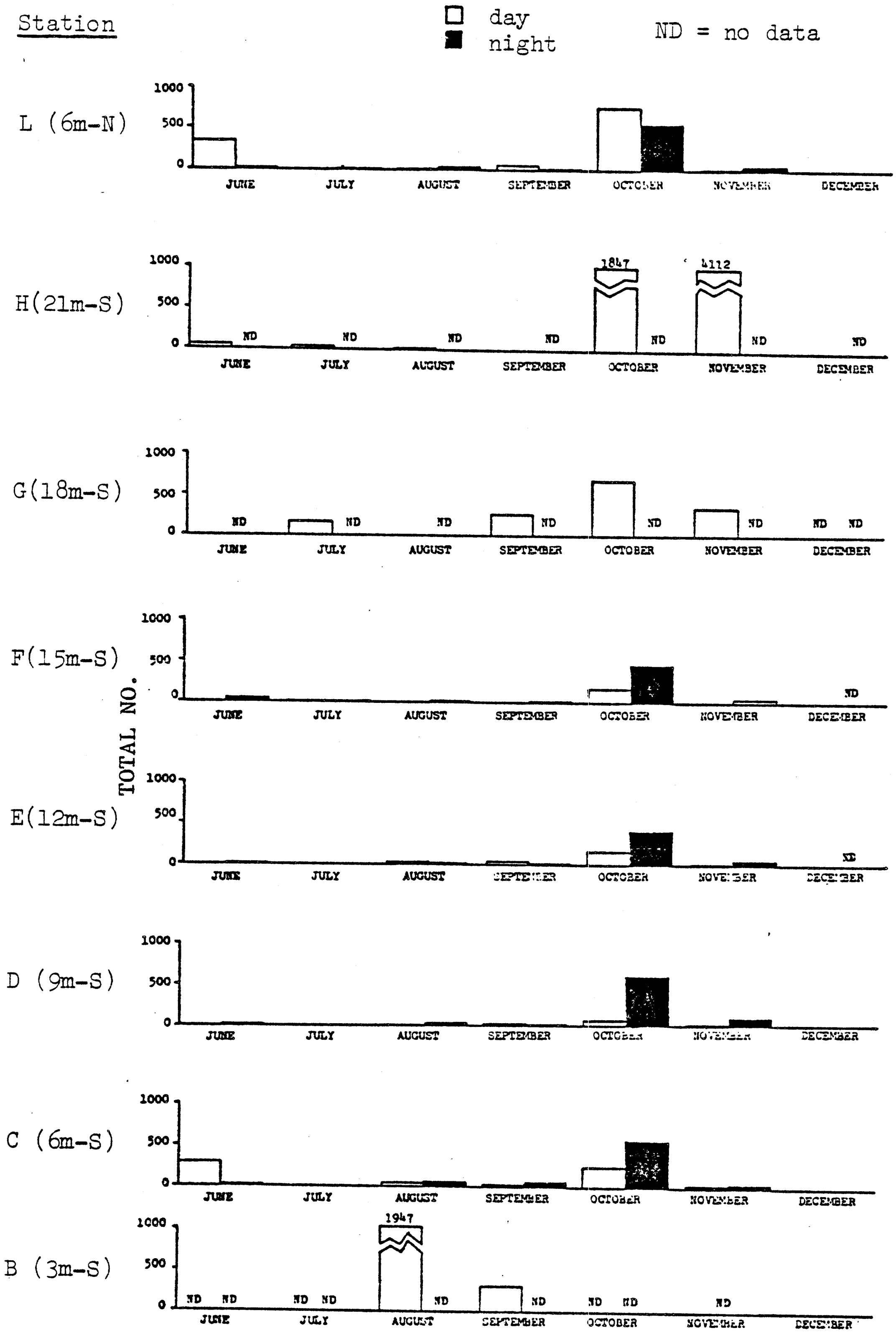


FIG. 17. Total number of alewife caught in duplicate trawl hauls in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, June - December 1977.

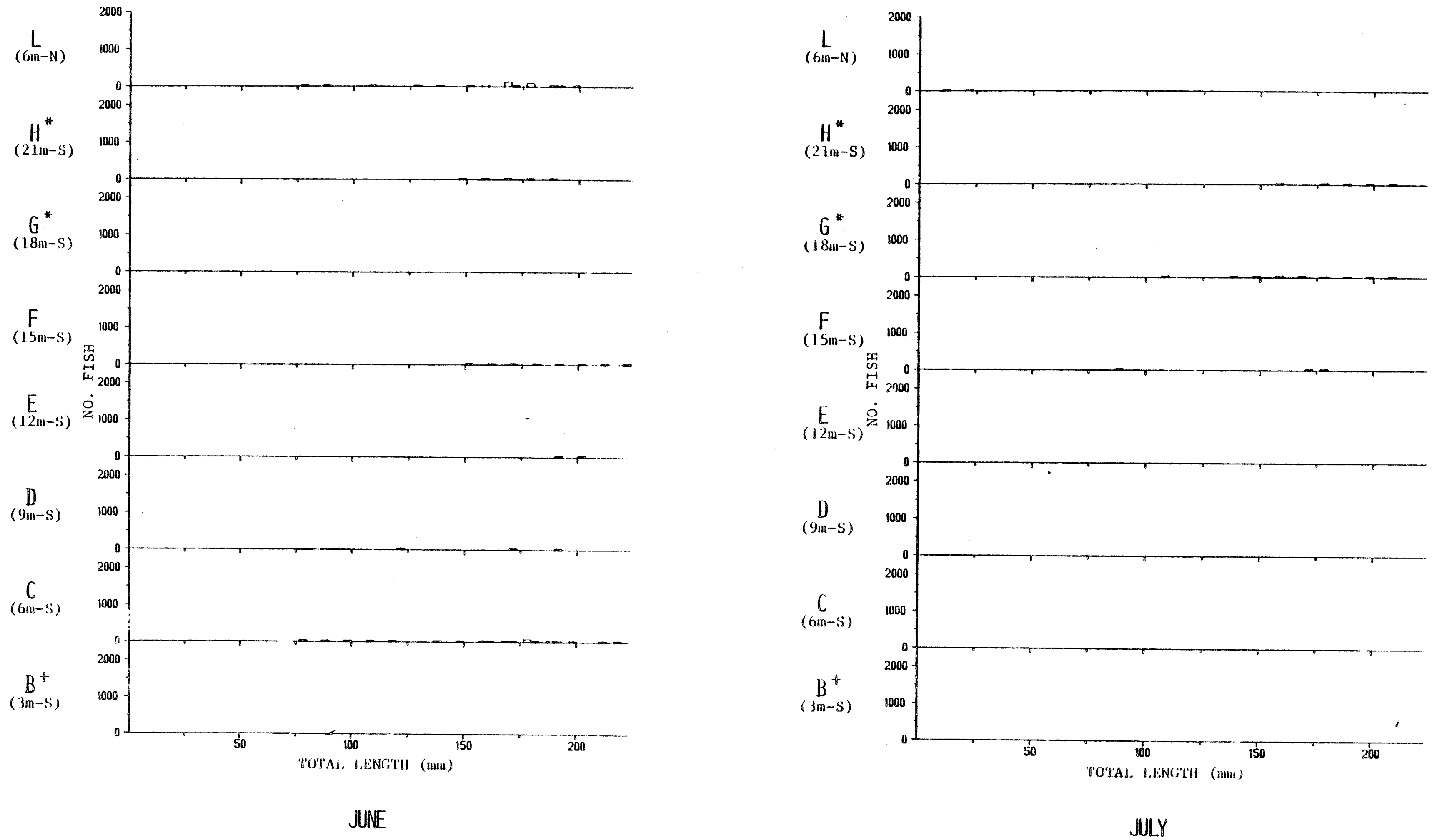


FIG. 18. Length-frequency histograms for alewife caught in duplicate trawl hauls during June to November 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.
* = No night sampling performed.
+ = No sampling performed.

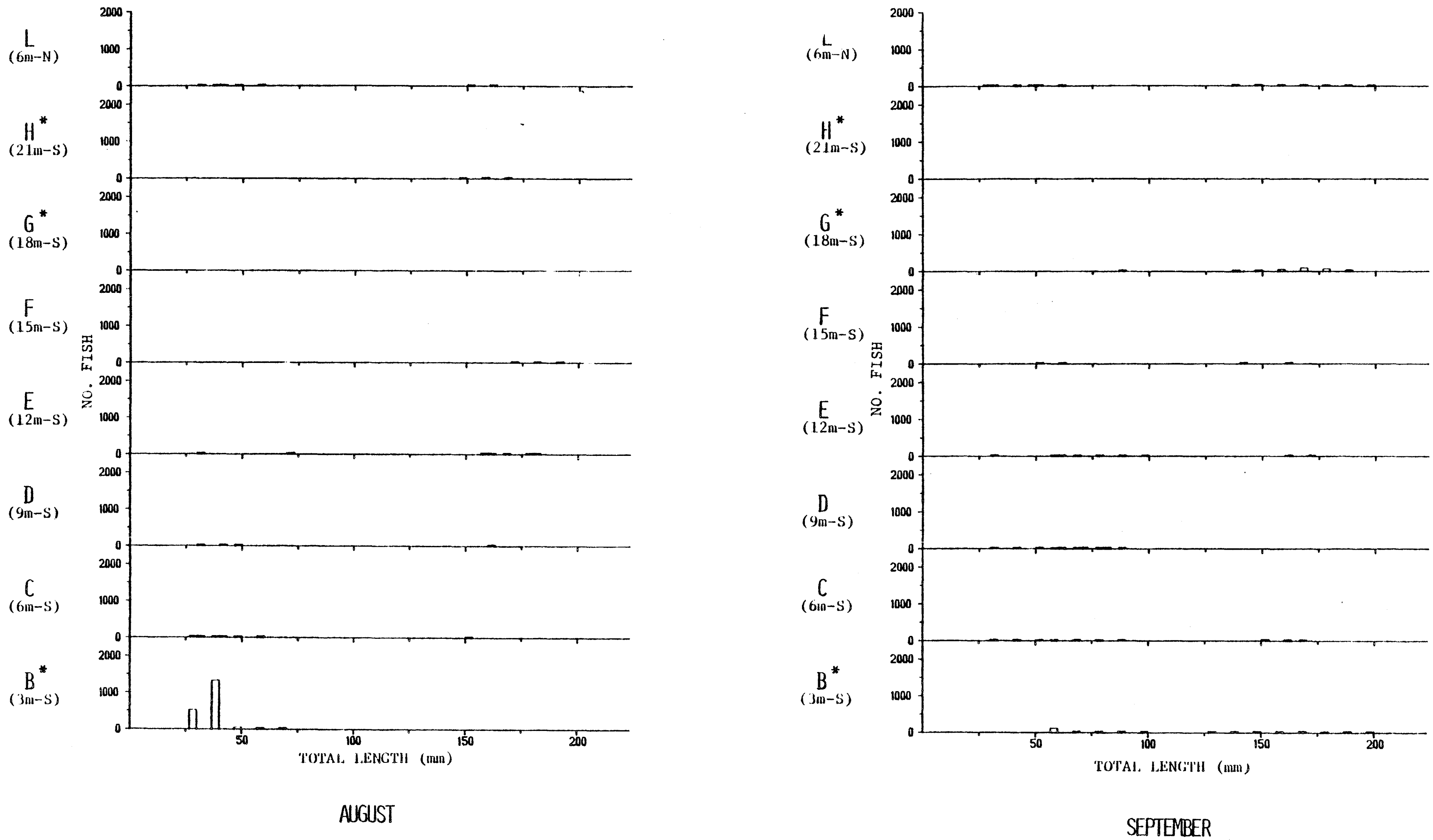


FIG. 18. (Continued)

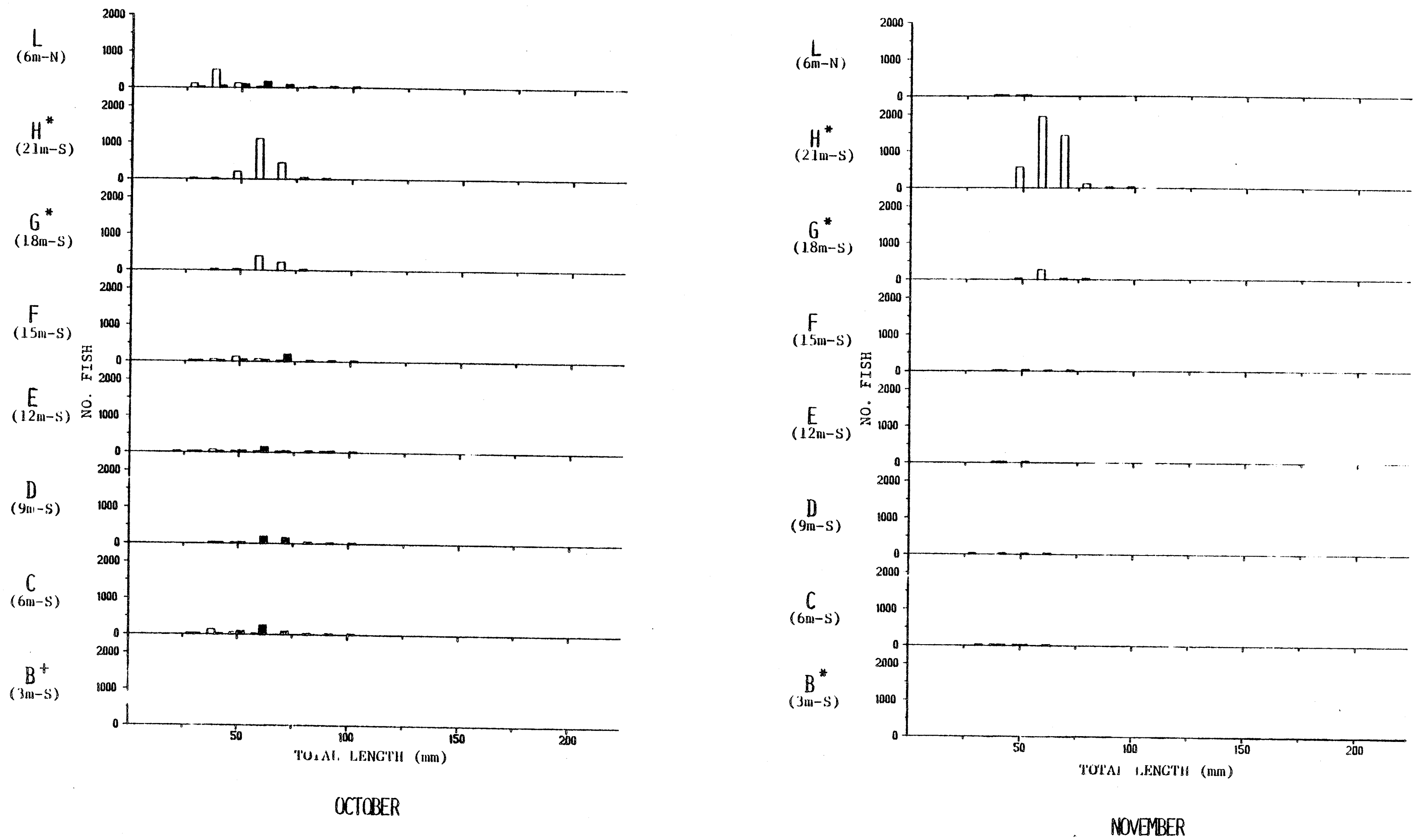


FIG. 18. (Continued)

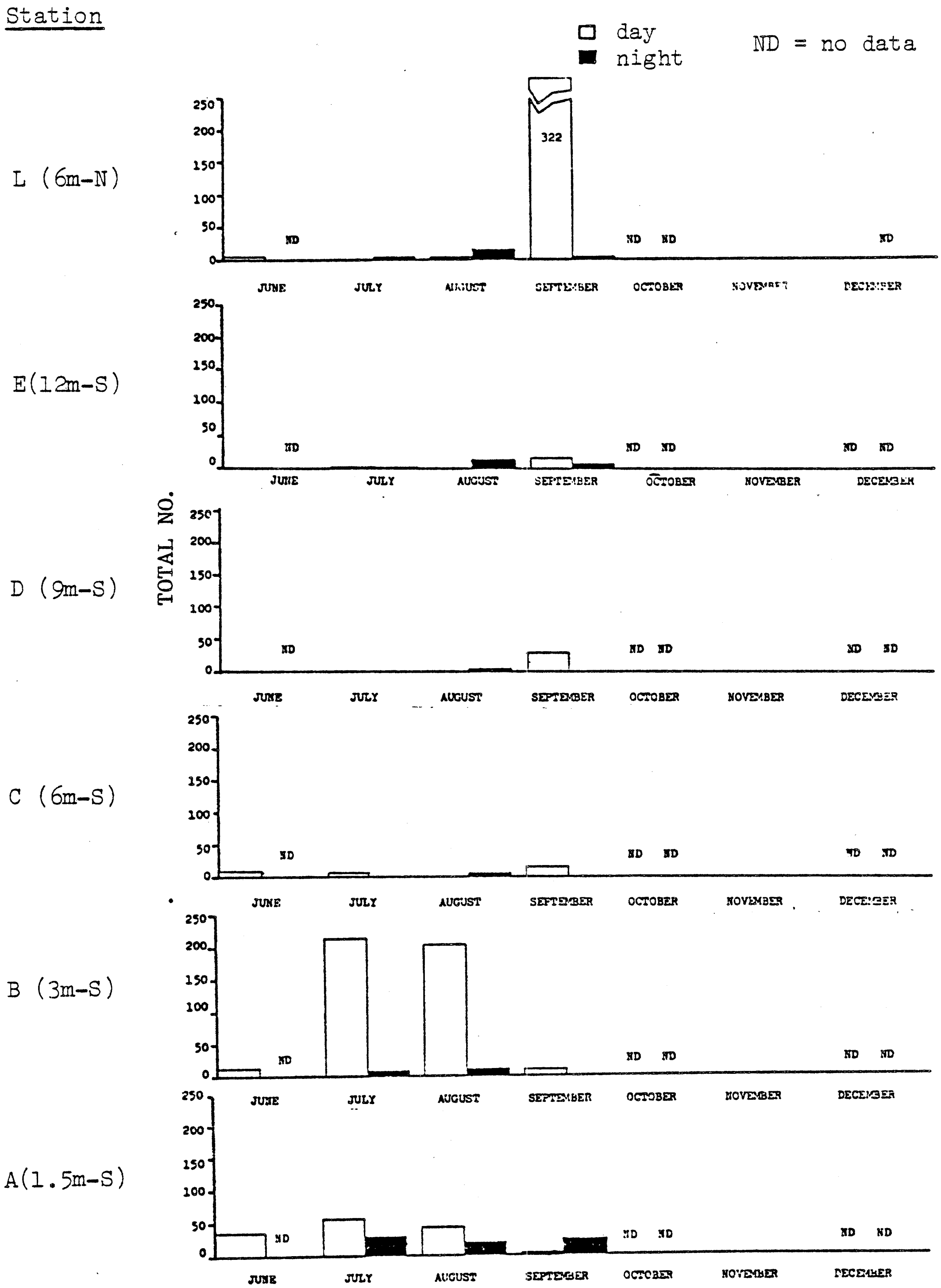


FIG. 19. Total number of alewife caught in duplicate bottom gill nets in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, June - December 1977.

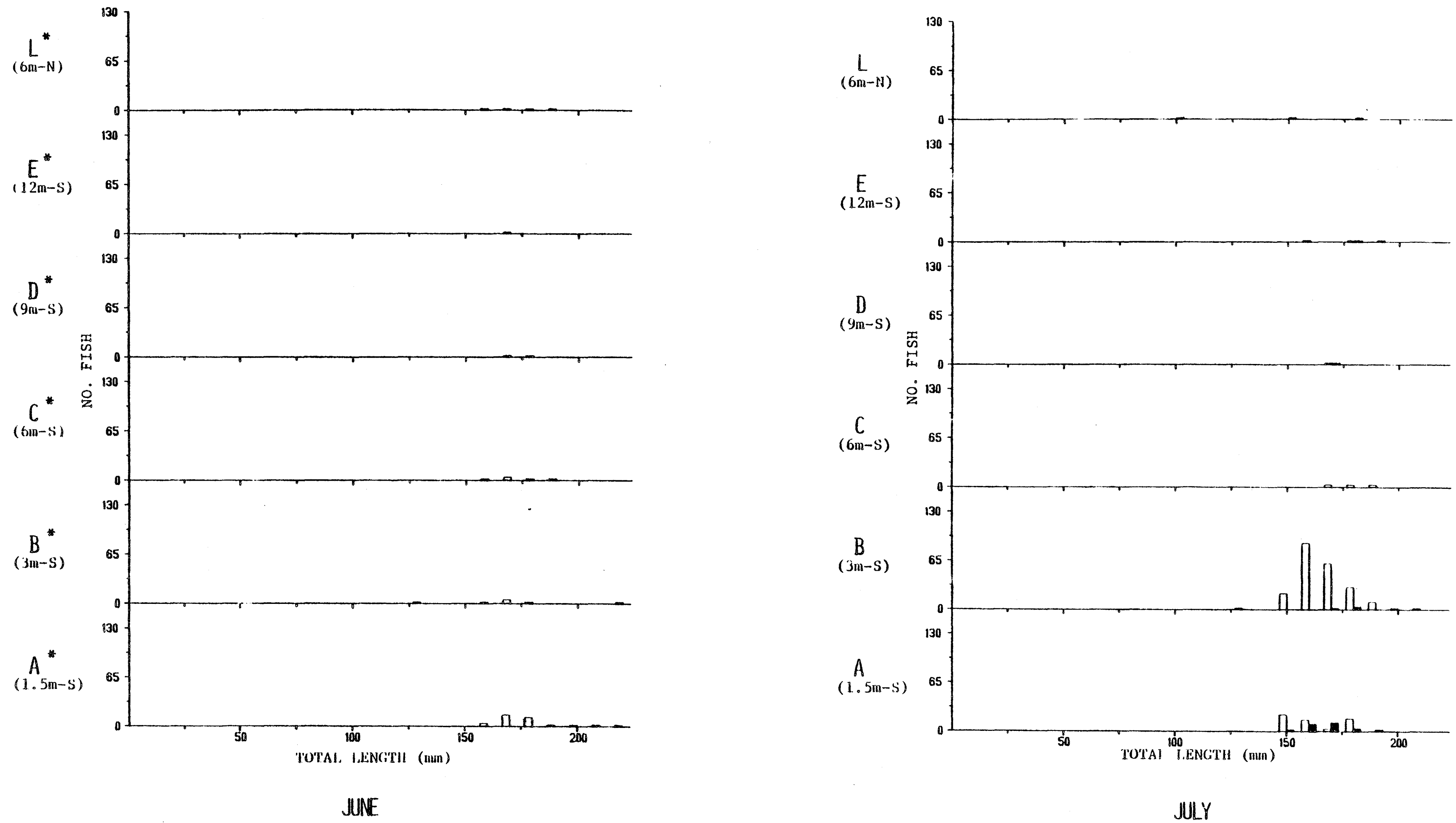
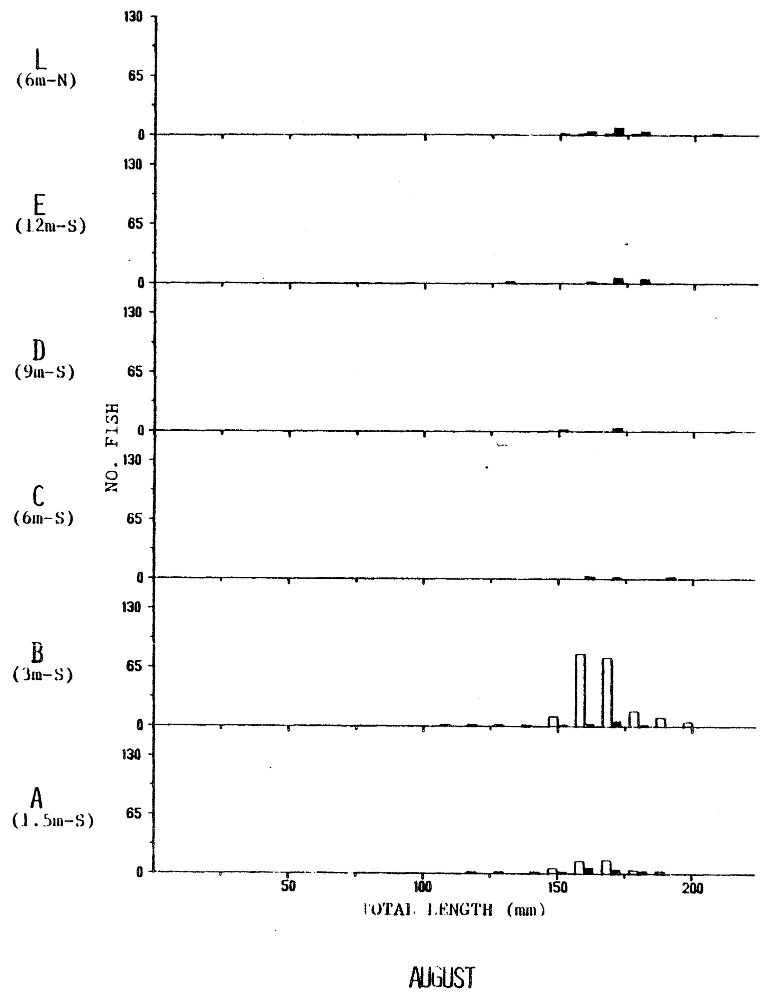


FIG. 20. Length-frequency histograms for alewife caught in duplicate bottom gill nets during June to November 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.
* = No night sampling performed.



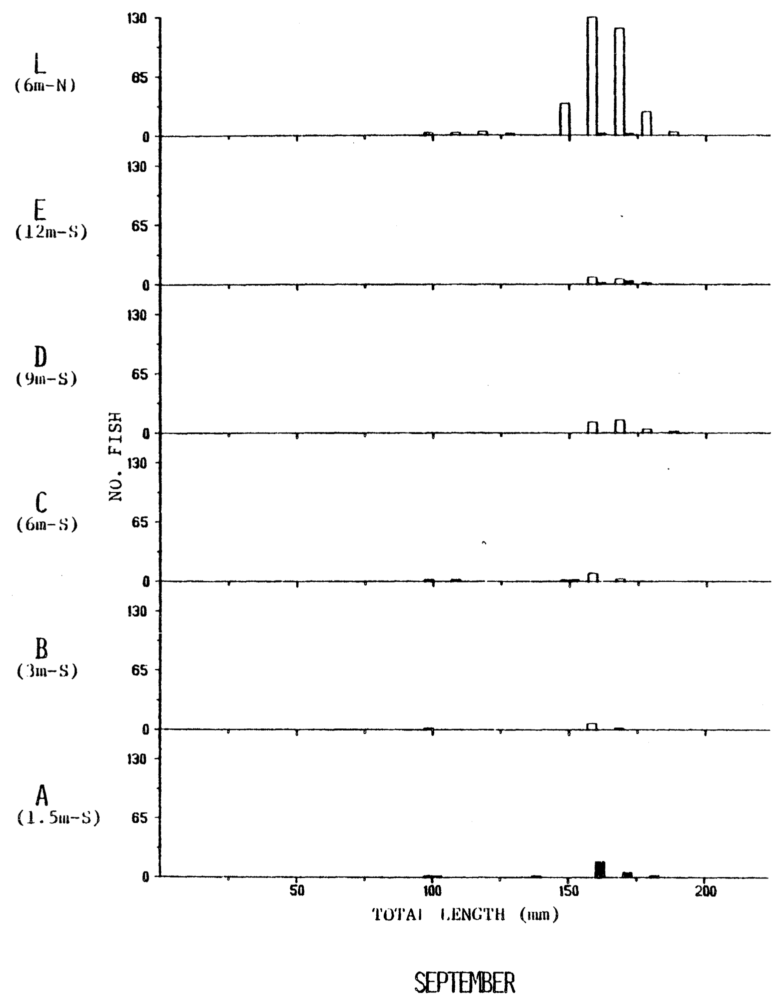


FIG. 20. (Continued)

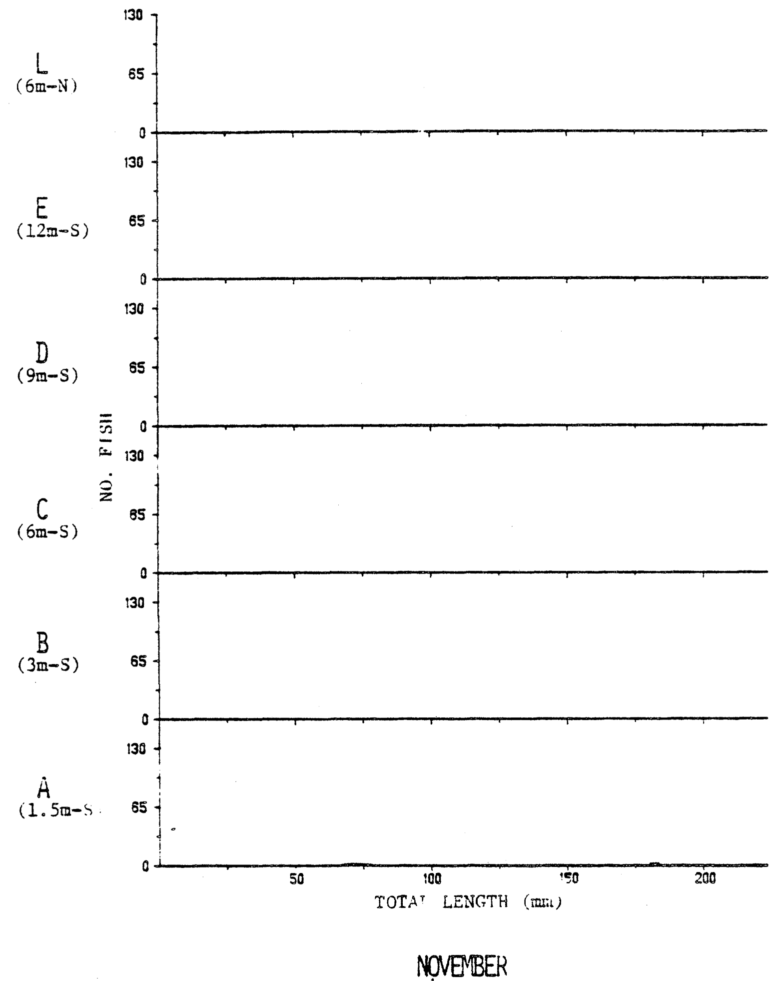


FIG. 20. (Continued)

explanation seems to be that alewives were moving parallel to shore and would not be vulnerable to a gill net set parallel to shore. It is noteworthy that trawling done with the current during the day at stations C (6 m - s.) and L (6 m - n.) accounted for 98% of the total catch. This may indicate that fish were moving parallel to shore against the current.

No alewives were caught in day seines at Lake Michigan beach stations, which demonstrated that alewives were probably concentrated between the beach zone and the 9 m contour during the day. Daytime net avoidance may also be an important factor.

At night adult alewives were found in the beach zone indicating a nocturnal shoreward movement as has been noted by Jude et al (1975). Large numbers (192-495 per station) were caught in seine hauls performed at Lake Michigan beach stations P, Q and R (Figs. 22 and 23). Differences between stations could have been due to schooling behavior

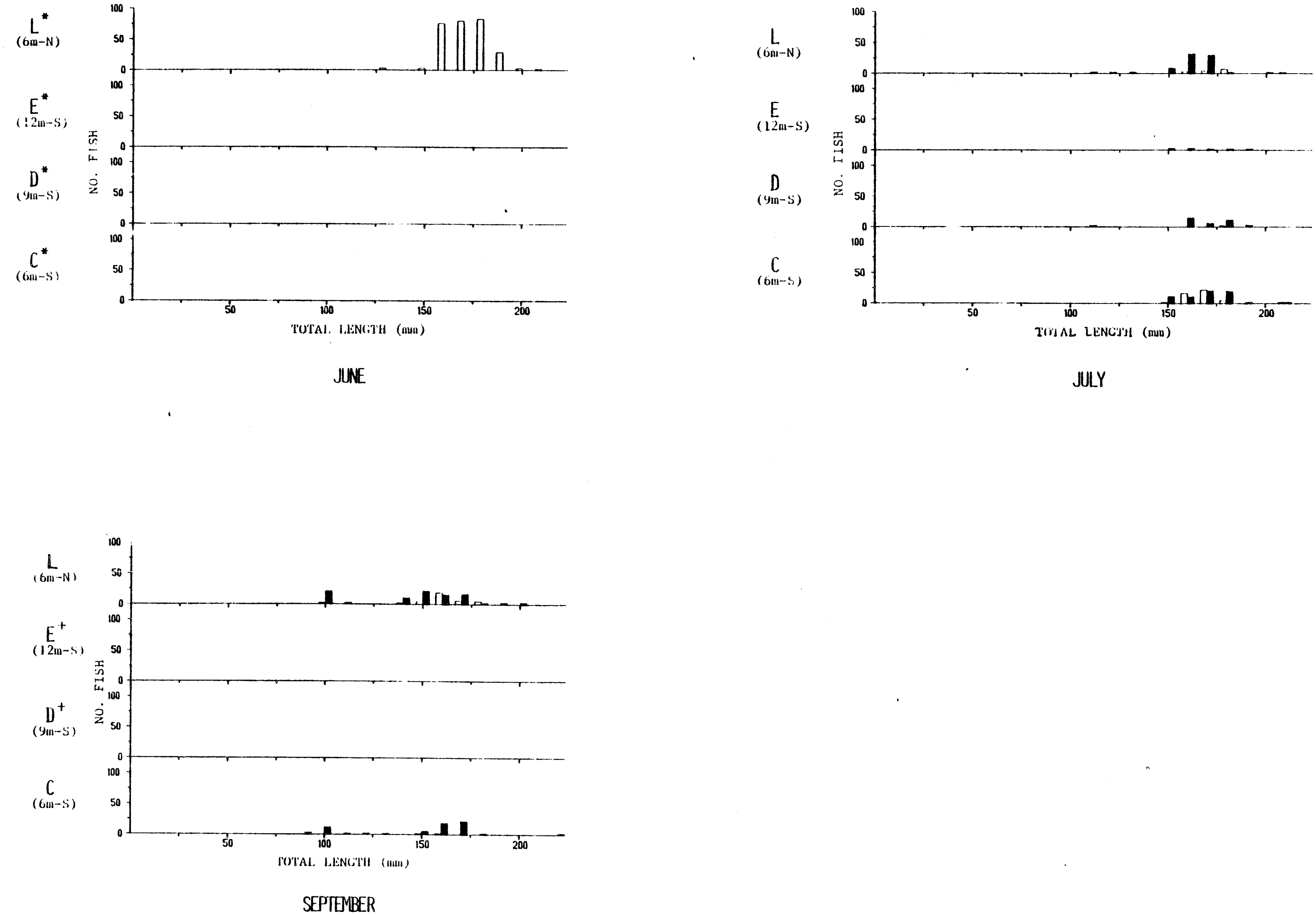


FIG. 21. Length-frequency histograms for alewife caught in duplicate surface gill nets during June to September 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.
+ = No sampling performed. * = No night sampling performed.

TABLE 22. Total number of alewife caught in surface gill nets fished during day and night once per month June through December 1977 in eastern Lake Michigan in the vicinity of the J. H. Campbell Power Plant. ND = no data.

Station		June	July	August	September	October	November	December
C (6M-S)	day	0	46	0	3	ND	0	ND
	night	ND	66	ND	68	ND	0	ND
D (9M-S)	day	0	1	0	ND	ND	ND	ND
	night	ND	36	ND	ND	ND	ND	ND
E (12M-S)	day	0	0	0	ND	ND	ND	ND
	night	ND	11	ND	ND	ND	ND	ND
L (6M-N)	day	278	15	0	38	ND	0	ND
	night	ND	76	ND	96	ND	0	ND

of alewife. Our findings over the year showed that schools of alewife were transient and that many catch differences between stations were due to random encounters with schools as described by Cooper (1961). Sexually spent individuals did not appear to remain in the spawning area as they constituted only a small portion of the catch.

From trawl data it appeared that alewife offshore distribution at night was more scattered than during the day, since alewives were caught at more depths. High concentrations encountered at 6 m during the day were gone as these fish were probably moving upward and toward shore from deeper water to spawn near the beach. Due to weather, no night gill net data are available for June.

In Pigeon Lake more adult alewives were caught during June than any other month (Appendix 4). Alewife may have spawned in Pigeon Lake based on occurrence of adult fish with both well developed and spent gonads and larvae (Table 23). Most adults were caught in the area influenced by Lake Michigan (stations: M - openwater and S - beach) (Figs. 24 and 25). More alewives were caught in bottom gill nets set at station M during the day than during the night, which agrees with their well known demersal distribution during the day and a more scattered surface

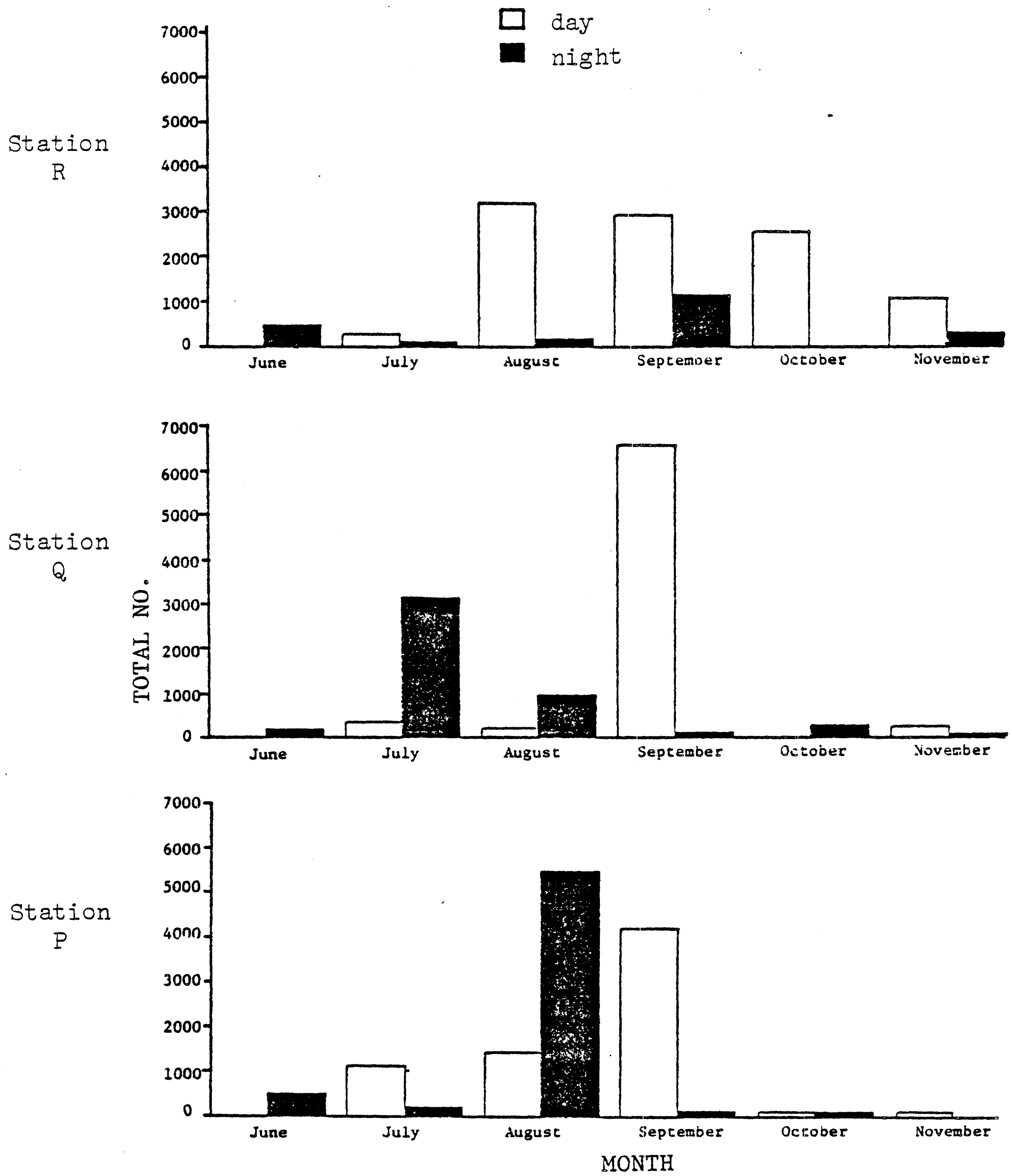


FIG. 22. Total number of alewife caught in duplicate seine hauls in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, June - November 1977.

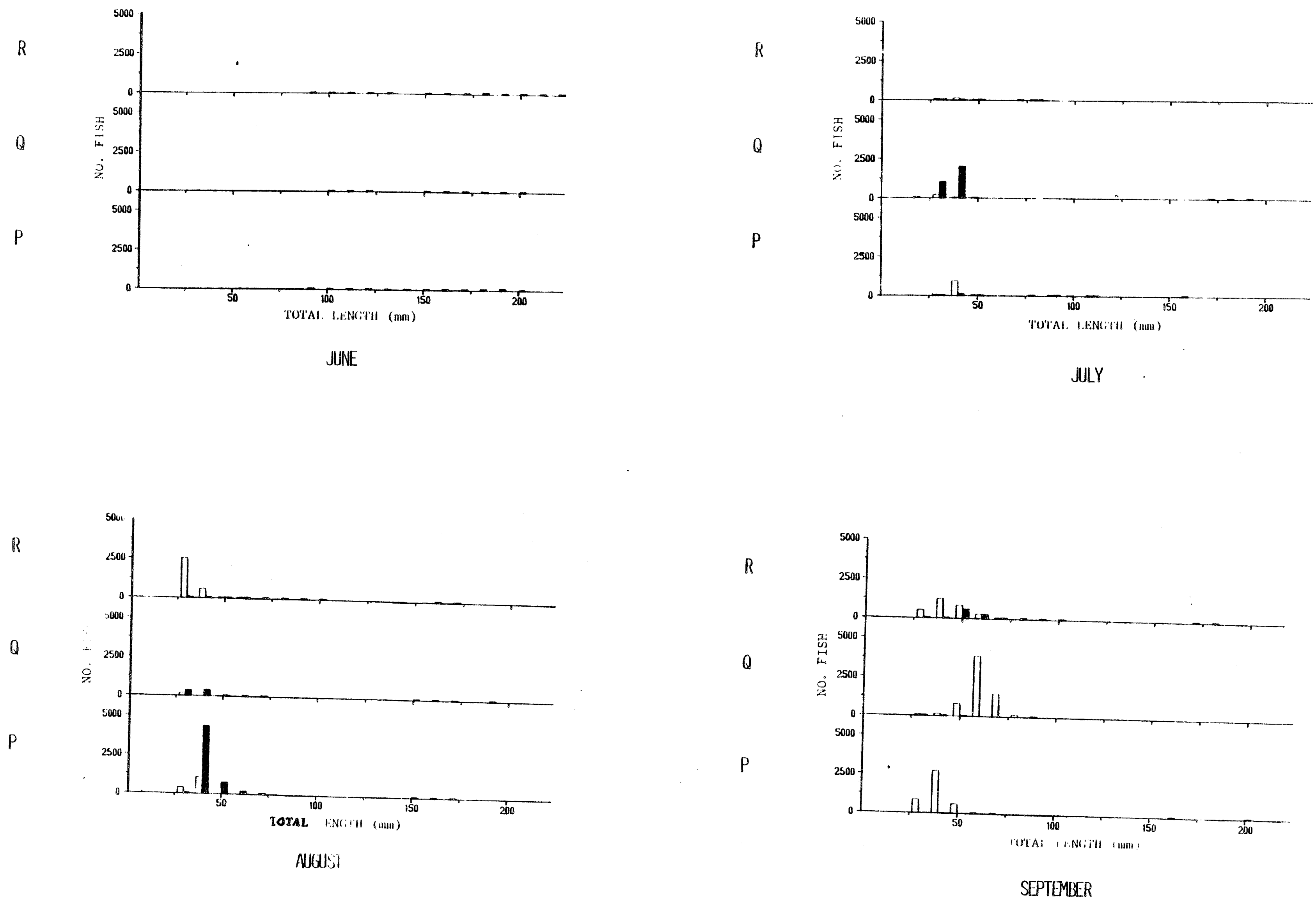


FIG. 23. Length-frequency histograms for alewife caught in duplicate seine hauls during June to Nobember 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.

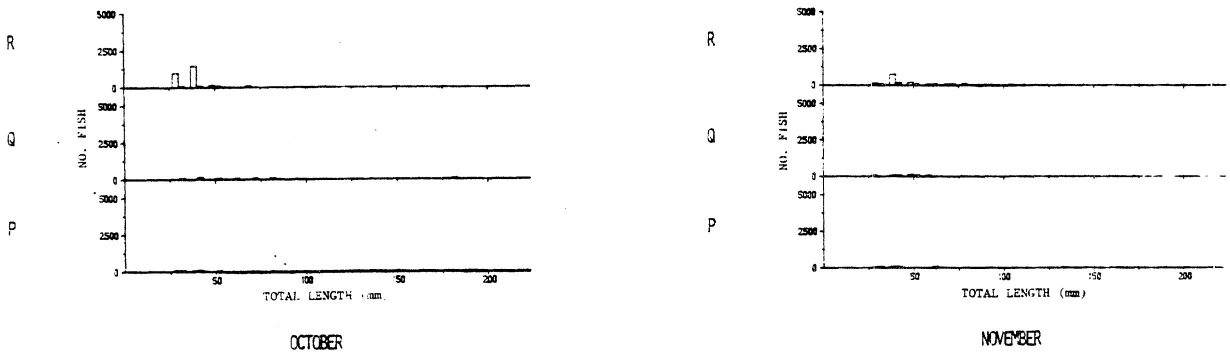


FIG. 23. (Continued)

distribution at night. One adult was caught by seine at beach station V (undisturbed Pigeon Lake) during the day. Alewife spawning was observed in Pigeon Lake during this period.

A 35 mm alewife was seined at beach station T (influenced by Pigeon River) on 1 June. Origin of this YOY fish is open to conjecture. It was either the result of very early reproduction (1 April) or very late reproduction from the previous year.

July -- Fewer adult alewives were caught during July in Lake Michigan compared to June; while, YOY appeared in great numbers, particularly in seine catches (Appendix 5). Fewer adults with well developed gonads were caught in July than during June (Table 21). A high percentage of females had gonads in the well developed state compared to males. During the day adults along the bottom were concentrated near 3 m and 18 m, based on trawl and gill net data. Few adults were taken in seines and bottom gill nets set at station A (1.5 m-s.); and station C (6 m - s.) bottom gill nets contained fewer fish than those set at station B (3 m - s.). Few alewives were caught in bottom gill nets or trawls between 6 and 15 m (Fig. 17, 18, 19, and 20). The explanation for the daytime distribution of these two groups of alewives at 3 and 18 m could be related to gonadal maturity. The inshore group contained many spent individuals, while the offshore group was composed of fish with developing gonads.

Day surface gill nets from stations C (6 m - s.) and L (6 m - n.) contained the most alewives, 46 and 15, respectively (Fig. 21 and Table 22) among the four stations where nets were set. More alewives were caught at station C (reference) than L (near the discharge) despite the fact that station C was 4.2 C cooler than station L. It appeared that differences in catch of this magnitude were due to different size schools encountering the nets rather than any increased population of

TABLE 23. Monthly gonad conditions of alewives caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Males	Slight development	2		4	2	1		
	Mod. development	1		2		2		
	Well developed							
	Ripe-running							
	Spent	2						
Females	Slight development	1		2	1			
	Mod. development	1						
	Well developed	4	1					
	Ripe-running							
	Spent	2						
	Absorbing							
Immature		1	79	17	22	1		1
Unable to distinguish								

alewives because of attraction to warmer water.

Day seine catches of alewife in July ranged from 250 to 1115 fish per station in Lake Michigan (Figs. 22 and 23). YOY, ranging in length from 20 to 50 mm, comprised 98% of the seine catches. Highest catch (1115) was at beach station P (s. reference). Station Q (s. discharge), which was 6 C warmer than the other two stations, yielded 372 alewives. Again water temperature did not appear to be an important factor in the determination of distribution.

Bottom gill net catches showed that alewives were present more at station B (3 m - s.) during the day than at night (Fig. 19 and 20). The highest catch (30) observed in bottom gill nets occurred at station A (1.5 m - s.) at night. Few adults were caught in seines during July. Four alewives were caught in all trawls at night in July, although no data were collected at stations B (3 m - s.), G (18 m - s.) or H (21 m - s.) (Fig. 17 and 18). Night surface gill net catch of alewives did increase over day catches at all stations with most being caught at stations C (6 m - s.) and L (6 m - n.) (Fig. 21). Apparently alewives moved into surface water during the night and spread out over a large area since increases in surface gill net catches from day to night occurred from 6 to 12 m.

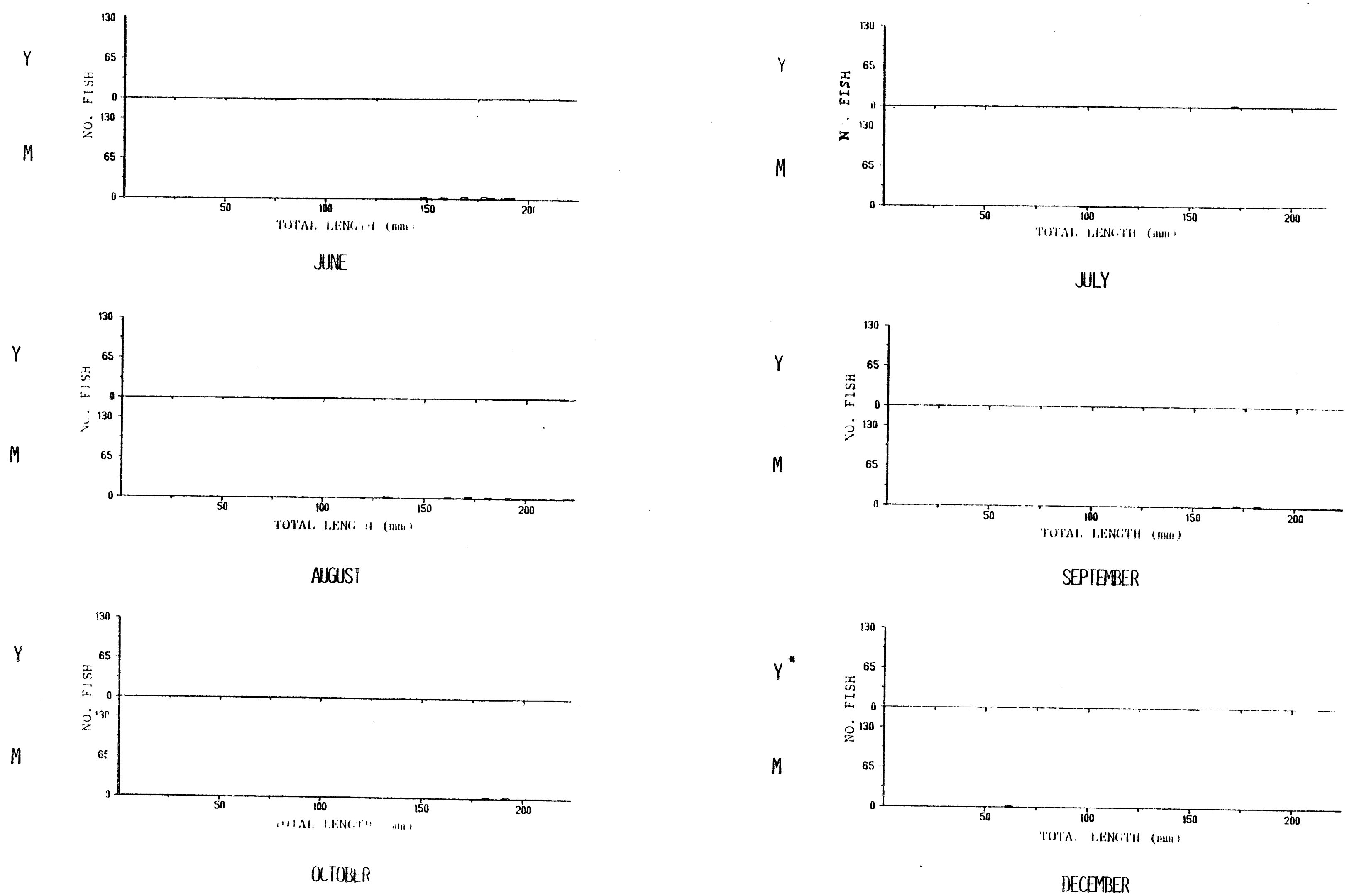


FIG. 24. Length-frequency histograms for alewife caught in duplicate bottom gill nets during June to December 1977 in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.
* = No night sampling performed.

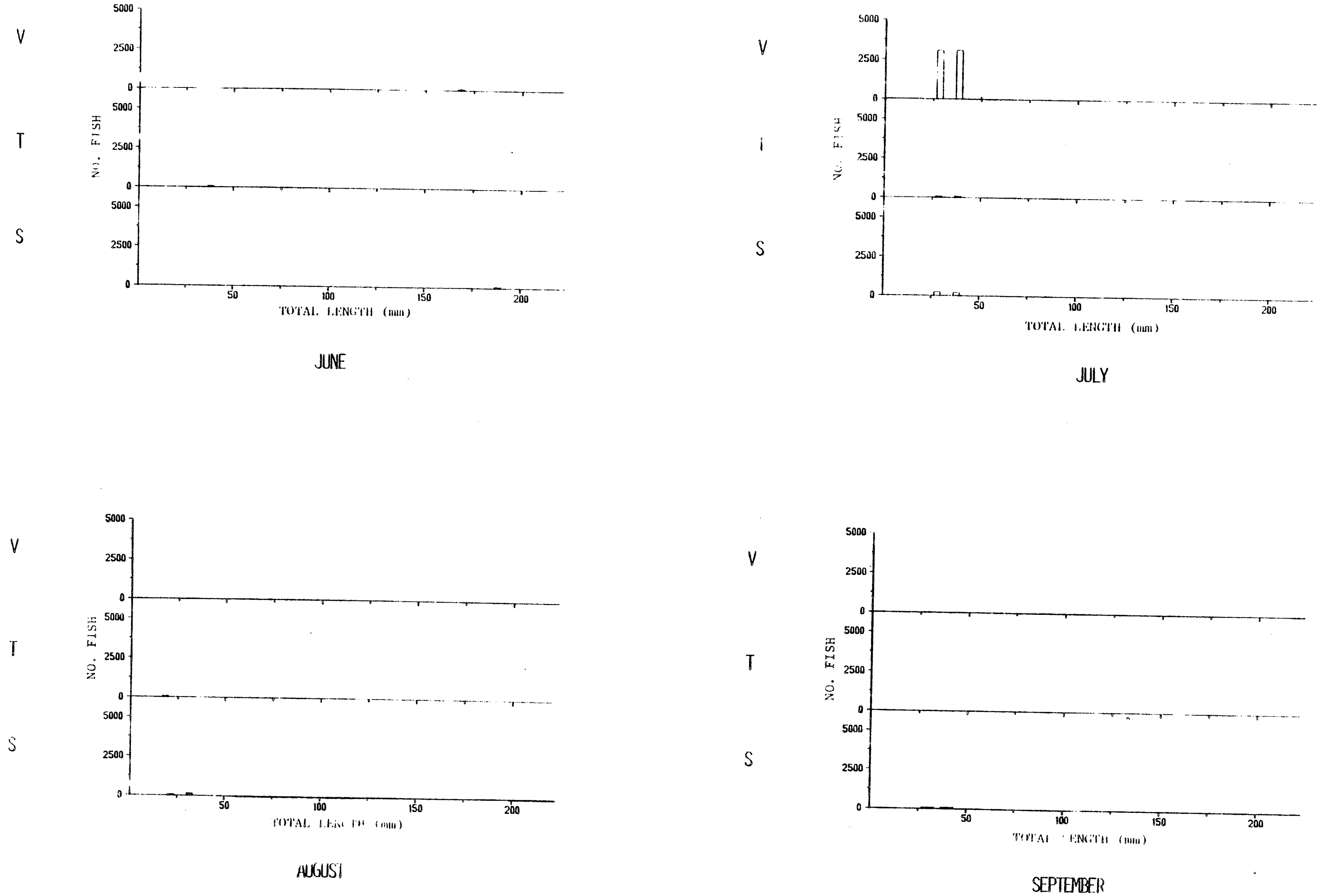


FIG. 25. Length-frequency histograms for alewife caught in duplicate seine hauls during June to October 1977 in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.

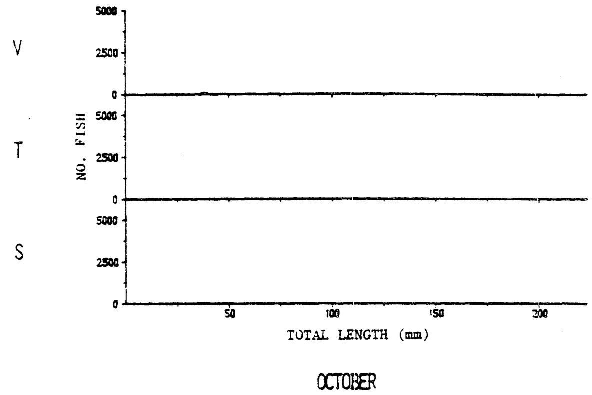


FIG. 25. (Continued)

Our sampling in mid-July occurred during an upwelling when water temperatures were approximately 10 C lower than in early July. Apparently alewives did not move into the inshore zone during night as normal which may have caused a temporary cessation in spawning. This hypothesis was strengthened by August larval alewife data which showed unusually low numbers of 12-19 mm alewife larvae in samples collected. Further analysis may indicate that absence of the 12-19 mm larval group coincided with those larvae which normally would have been spawned during the upwelling period. Nocturnal movement was apparently more vertical than shoreward. Surface waters were 4.3-8.0 C warmer than bottom waters which may at least partially explain why alewives sought surface waters during the night.

There were large differences in seine catches at Lake Michigan beach stations during July at night. Catches at stations P (s. reference), R (n. discharge), and Q (s. discharge) were 183, 42, and 3115, respectively (Figs. 22 and 23). Station Q was 3-4 C warmer than station P and R during the night which may account for the highest seine catch at station Q, yet station Q during the day was 6 C warmer than the other beach stations, but accounted for far fewer alewives (372) than station P (1115). Therefore temperature did not appear to be a good explanation for catch differences between stations as results were conflicting.

In Pigeon Lake during July only one adult alewife, a female with well developed gonads (Table 23), was caught in a gill net set at openwater station Y, (influenced by Pigeon River) (Fig. 24). Spawning in Pigeon Lake may therefore occur into July. More alewives (YOY) were caught during July in Pigeon Lake than in Lake Michigan despite greater effort with different gear in Lake Michigan. Most YOY seined in Pigeon Lake were caught at beach station V (94%) (Fig. 26). These YOY probably resulted from early spawning that took place in Pigeon Lake. The catch of alewives from beach station S (influenced by Lake Michigan)

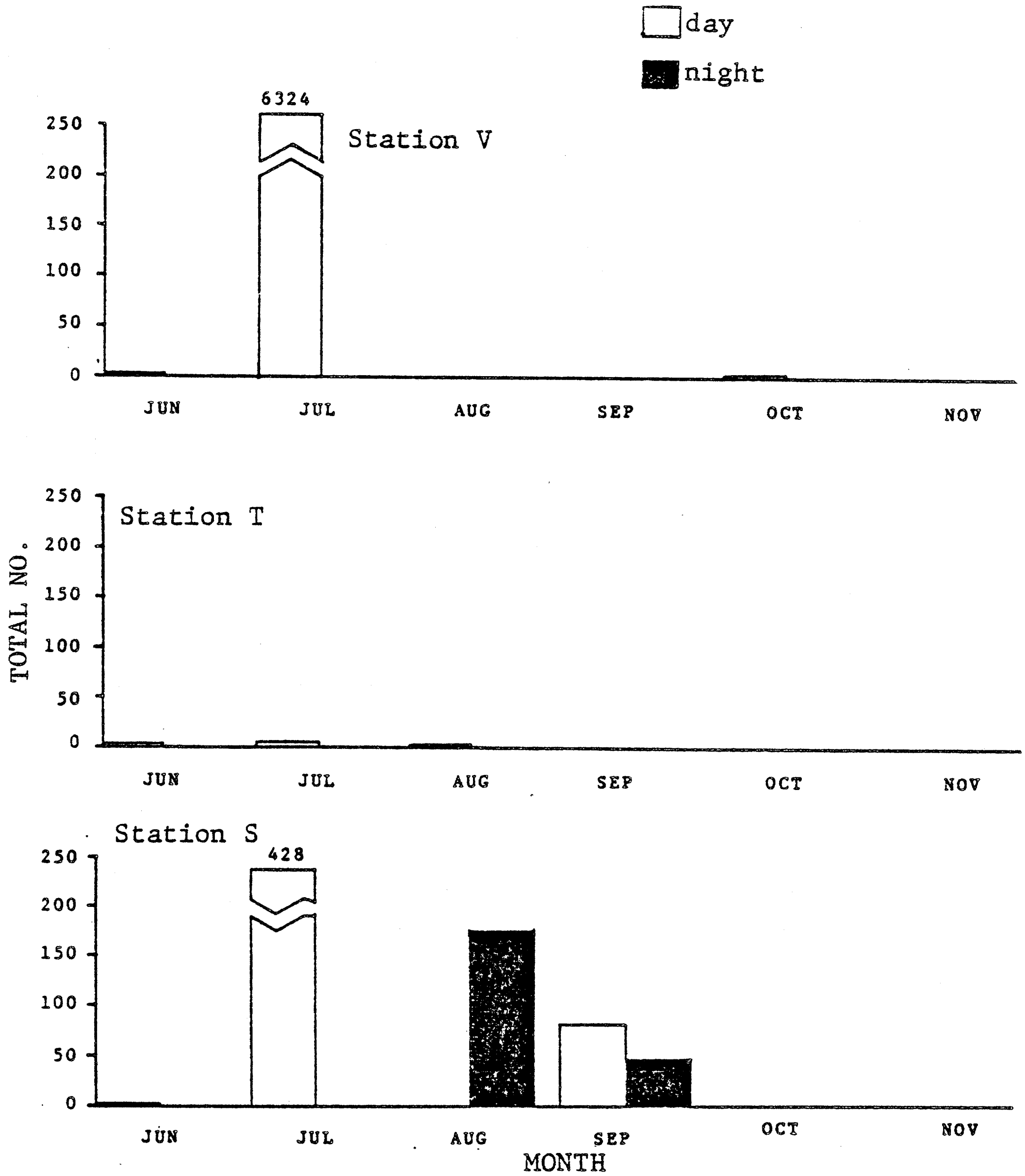


FIG. 26. Total number of alewife caught in duplicate seine hauls in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, June - November 1977.

constituted 6% and that from station T (influenced by Pigeon River) represented < 1% of the total alewife catch for July (Fig. 25). YOY caught during July ranged from 30-50 mm. The area surrounding station V (undisturbed Pigeon Lake) is very shallow and quite productive, an area where young alewives would probably find abundant food, and cover for protection from predators as well as preferred water temperatures. Concentrations of alewife larvae at station T in early June were among the highest recorded in Pigeon Lake , yet few YOY (five) were seined there at the end of July. It seems possible that growing YOY would migrate downstream as they do in spawning streams along the Atlantic Ocean (Cooper 1961).

Drastic differences occurred between seine catches of alewife during the day and night in Pigeon Lake, which were unlike those observed at beach stations in Lake Michigan. Despite catching thousands of alewife YOY at beach station V (undisturbed Pigeon Lake) during the day, no alewives were caught there at night. This phenomenon was true for the other Pigeon Lake beach stations as well. Apparently, YOY moved offshore at night. An offshore movement from beach stations at night was documented for YOY alewives in Lake Michigan at the Cook Plant (Jude et al 1975). Entrainment of alewife fry at Campbell also increased at night during July. In addition, plankton nets collected large numbers of fry at night along beach station S (influenced by Lake Michigan), while the seine collected none. The reason for this is not understood.

August -- General daytime distribution of adult alewives in August appeared similar to that of July with most adults concentrated around the 3 m contour. High numbers of adult alewives (205) were taken in bottom gill nets at station B (3 m - s.), while fewer (44) were caught at station A (1.5 m - s.), and none were caught at stations C (6 m - s.), D (9 m - s.), or E (12 m - s.). Only five adult alewives were caught at station L (6m - n.) No surface gill nets were set. Day seine catches were high during August (Fig. 22) with all alewives caught being YOY (Fig. 23). Numbers of alewife caught ranged from 189 at beach station Q (s. discharge) to 3167 at station R (n. discharge). As water temperatures at the three beach stations were all 25 C $\pm$ 0.5, catch differences between stations were probably due to the size of the alewife school that happened to be in the area at the time of sampling.

Very few adult alewives were caught by trawls during the day probably due to net avoidance. Nine adult alewives were caught at station E (15 m - s.), four at station H (21 m - s.) and three at station L (6 m - s.).

YOY alewives appeared to be concentrated from the beach zone out to 6 m during the day. Large numbers of YOY alewife (1947) were trawled at station B (3 m - s.) during the day, while few (43) were caught at station C (6 m - s.) (Fig. 18). Only one YOY was caught at station D (9

m - s.) and none were caught at deeper stations.

At night, seine data showed that numbers of YOY alewives in the beach zone remained high. Catches of YOY ranged from 121 at station R (n. discharge) to 5395 at station P (s. reference). Again water temperatures were nearly the same (± 1 C) and differences in catches seemed attributable to natural variation rather than any real differences in distribution. Low numbers of adults (4-23) were present in night seine catches at the three beach stations. A few adults were also caught at each trawling station with the most (14) caught at the deepest station, station F (15 m - s.). Night trawl catches were greater than day catches at stations C (6 m - s.), D (9 m - s.), F (15 m - s.) and L (6 m - n.) (Fig. 17). Higher night catches were probably due to an offshore movement of YOY, more widespread distribution of adults and less net avoidance. No YOY were caught deeper than station E (12 m - s).

Bottom gill net catch of adults at station A (1.5 m - s.) and B (3 m - s.) dropped dramatically from 44 and 205 during the day to 18 and 11, respectively, at night. All catches of adults in bottom gill nets set between 6 and 12 m increased at night compared to day samples. Gill net and seine data, indicated that adult alewives were widely distributed at night in August over an area including the beach zone to at least the 12 m contour. Few alewives with well developed gonads were caught in August indicating that the spawning period was over or nearly so by this time (Table 21). Many fish showing slight gonad development could have been spent individuals as the gonads look similar in the two cases.

Water temperatures in Pigeon Lake in July were probably at their maximum, particularly at beach station T (influenced by Pigeon River) which may have inhibited movement of spawning alewives into these areas. Limited information exists about temperature preference of alewife (Carroll 1973, Otto et al. 1976), but water temperatures above 19 C may be avoided. Only one alewife was caught in August during the day in Pigeon Lake; a YOY seined at beach station T (influenced by Pigeon River) (Appendix 5). At night eight adult alewives were caught in a bottom gill net at 6 m openwater station M (influenced by Lake Michigan) (Fig. 24 and Table 24). Adult alewives in Pigeon Lake either showed slight or moderate gonadal development (Table 23), so that spawning appeared to be minimal during August in Pigeon Lake. At beach station S (influenced by Lake Michigan) there was a dramatic increase at night in the number of YOY alewives caught which was not seen at other Pigeon Lake beach stations.

Normally, YOY alewife catches are higher at beach stations during the day than at night because of nocturnal offshore movement (our data from other months and Jude et al 1975). August seemed to be an

TABLE 24. Total number of alewife caught in bottom gill nets fished during day and night once per month June through December 1977 in Pigeon Lake (Port Sheldon, Michigan). ND = no data.

Station		June	July	August	September	October	November	December
		Month						
M (6M)	day	9	0	0	0	0	0	0
	night	3	0	8	6	3	0	1
Y (1.5M)	day	0	0	0	0	0	0	0
	night	0	1	0	0	0	0	ND

exception since only Lake Michigan beach station R (n. discharge) seine catches followed the pattern. Seine catches at stations P (s. reference), Q (s. discharge) and S (Pigeon Lake - influenced by Lake Michigan) were higher at night than during the day.
This deviation from the other months results is difficult to explain. The total absence of YOY during the day at station S and lower numbers at stations P and Q could have been the result of patchy distribution of YOY and our nets missing the schools, but this seems unlikely. Net avoidance may have been a factor in reducing day seine catches, but it is difficult to understand why this would have only affected certain stations and months (i.e., August).

September -- Large numbers of YOY alewives were seined in the beach zone of Lake Michigan during September. Numbers caught ranged from 2893 at station R (n. discharge) to 6570 at station Q (s. discharge) (Fig. 23). All alewives caught in day seines were YOY. Spawning had ceased in September according to our gonad data (Table 21). No individuals with well developed, ripe or spent gonads were found.

Trawl catches contained a mixture of YOY and adults during September (Fig. 17). The largest trawl catch at station B (3 m - s.) contained 229 YOY and 91 adults (Fig. 17). Low numbers of YOY were also caught at stations C (6 m - s.), D (9 m - s.), G (18 m - s.) and L (6 m - n). The most adults (260) were trawled at station G. The other sizable catch of adults (52) occurred at station L. Adults were scattered throughout the study area since they were caught at all stations except D (9 m - s.) and F (15 m - s.). September data indicates a gradual movement toward deeper water by both YOY and adult alewives.

Bottom gill net catches, ranging from 3 to 32 fish, were fairly uniform along south transect stations (Figs. 19 and 20). Most alewives caught were adults, but a few YOY greater than 100 mm in length were caught. A very large catch (322) at station L (6 m - n.) was ten times larger than any gill net catch along the south transect; 95% of the catch was adults. No water temperature difference existed between the two 6 m stations, C and L; apparently larger numbers of adult alewives were present in the area of the thermal discharge. Day surface gill net catch at 6 m station L was higher than that of the reference station C which corresponded with results from bottom gill nets (Figs. 20 and 21). No significant difference in bottom gill net catches was apparent at night between stations C and L.

The largest night catch in bottom gill nets occurred at station A (1.5 m - s.) where 26 alewives were caught. All were adults but one. Other catches along the south transect ranged from one to six fish. Only two alewives were caught at station L (6 m - n.). Compared to day catches, night surface gill net catches increased at both stations C (6 m - s.) and L indicating that adults were moving off the bottom at night.

Numbers of alewives caught in seines at night were lower than day catches. This decline in number was due to decreased catch of YOY. This age group began to migrate offshore at night. A few adults were caught at night in seines indicating some movement by adults toward shore.

Night trawl catches of YOY were larger than day catches at station C (6 m - s.), additional evidence for an offshore movement of YOY. There was a slight increase at night in the number of YOY caught in trawls at station L (6 m - n.).

Data from three stations, C (6 m - s.), D (9 m - s.) and E (12 m - s.), were compared for differences in mean length of YOY alewives for day and night trawl catches. These stations were selected because data were available for both day and night. Mean length of alewives in day samples collected at the three stations ranged from 73.2 to 75.3 mm while mean lengths for night samples ranged from 40.1 to 49.6 mm. YOY alewives found in deeper water at night are thought to come from the beach zone since numbers caught in seines were lower at night than during the day. Larger YOY found on the bottom during the day migrated upward at night as shown by the occurrence of larger YOY in night surface gill net catches in September.

No alewives were caught in bottom gill nets in Pigeon Lake during September. At beach station S (influenced by Lake Michigan) numerous YOY were caught by seines both during the day and night. Like Lake Michigan, fewer were caught during the night than during the day.

Adults caught during September showed only slight gonadal development (Table 23).

October -- The most striking change in the distribution of alewives between September and October was the general disappearance of adult alewives from the Lake Michigan study area. Only one adult male (moderate gonadal development) was taken during our sampling and that was from a night seine haul at beach station Q (s. discharge) (Fig. 23). During the day, YOY alewives were prominent in all trawl catches (Fig. 18). The largest catch (1847) was made at the deepest station, H (21 m - s.), showing the offshore movement by YOY alewives. Large differences in seine catches occurred during the day, ranging from zero at station Q (s. discharge) to 2588 at station R (n. discharge). Only six alewives were seined at station P (s. reference). The water temperature difference between stations was only 2.8 C so it was unlikely that this factor was responsible for the large variability observed.

At night in October, seine catches were as low as they were in September, ranging from four at station R (n. discharge) to 252 at station Q (s. discharge) (Fig. 22). Numbers of alewives (YOY) caught in trawl hauls increased at night when compared with day catches at all stations except L (6 m - n.). Catches ranged from 397 to 591 along the south transect.

Larger YOY were found in trawl catches during the night than during the day, which was opposite to the pattern observed in September. Mean lengths of YOY caught at stations C (6 m - s.), D (9 m - s.), E (12 m - s.) and F (15 m - s). were calculated. Mean length of alewife YOY increased with increasing depth and ranged from 40.8 to 50.2 mm. This phenomenon has also been observed by Wells (1968). At night no increasing trend in YOY lengths was observed and mean lengths ranged from 61.4 to 65.7 mm. Net avoidance is a possible explanation for catching larger fish at night than during the day, but does not appear to be the best explanation for this situation. The alewives in question (the larger of the YOY around 70-100 mm) were represented in other day trawl catches throughout the study period (June through November), indicating that at least during these times they were not avoiding the trawl during the day.

Another possible explanation for the diel changes in lengths of alewives in trawl catches was a nocturnal shoreward migration of larger YOY found in deeper water during the day. Alewives with lengths up to 90 mm were caught at station H (21 m - s.) during the day. Maximum size of alewives decreased with depth in day trawl catches. At night, the maximum size of alewives caught increased at inshore stations when compared with offshore stations approximately to the maximum size found at deeper stations during the day.

A few adult alewives were caught in Pigeon Lake during October at station M (influenced by Lake Michigan) in a night bottom gill net (Fig. 24 and Table 24). YOY numbers dropped considerably from September as only one was caught in a seine at beach station V (undisturbed Pigeon Lake) (Fig. 25). Adults caught during October showed only slight to moderate gonadal development (Table 23).

November -- Results of sampling during November were similar to those observed in October. Very few alewife adults appear to have been in the area as only one male was caught in Lake Michigan, in a bottom gill net set at night at station A (1.5 m - s.) (Fig. 20). All other alewives caught were immature (Table 21). Day seine catches of alewife ranged from ten at station P (s. reference) to 1075 at station R (n. discharge) (Fig. 22 and 23). Trawling data showed that numbers of YOY declined from the beach zone to the 9 m contour. Numbers were low between the 9 and 15 m contours. At deeper stations G (18 m - s.) and H (21 m - s.), concentrations of YOY alewives increased to a maximum of 4112 at station H. As in October, maximum length of YOY increased with increasing depth.

At night numbers of YOY caught increased at all stations where trawling was performed when compared with day catches. No alewives were caught in surface gill nets indicating that a horizontal rather than vertical migration of larger YOYs was occurring. YOY longer than 85 mm, present in earlier months, were not caught in November indicating that larger YOY had moved from the study area by this time.

No alewives were caught in Pigeon Lake during November. Therefore it appears that Pigeon Lake does not have an overwintering population of alewives.

December -- By December nearly all alewives appear to have left the study area. No alewives were caught in day or night trawls in Lake Michigan. No gill netting or seining was done during this month in Lake Michigan. The only alewife caught during December was a YOY taken in a bottom gill net set at openwater station M (influenced by Lake Michigan) in Pigeon Lake (Fig. 24 and Table 24).

Temperature-Catch Relationships -- In Lake Michigan, YOY alewife appeared to be caught in warmer water than adults. Adults were rarely caught above 18 C while YOY were caught in water as warm as 30 C (Fig. 27). Otto et al. (1976) indicated that YOY had a higher temperature preference than adults and our field results in Lake Michigan seem to provide evidence for this finding.

The pattern of YOY being taken at warmer temperatures than adults in Lake Michigan was not observed in Pigeon Lake. Adult alewife in Pigeon Lake were caught at water temperatures up to 21 C and YOY were collected at temperatures up to 23 C, a small difference (Fig. 27). Unlike Lake Michigan, the range of water temperatures during warmer

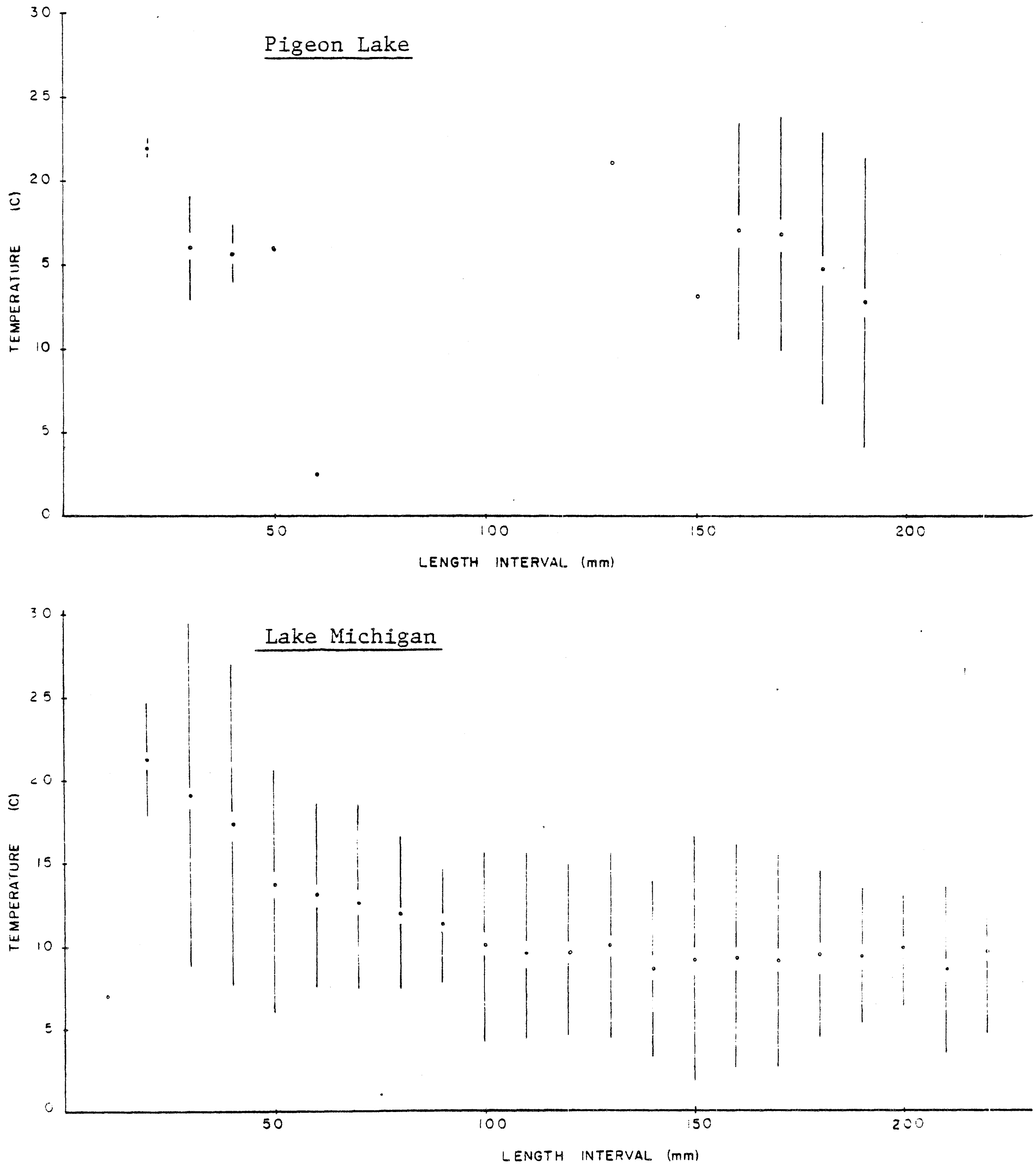


FIG. 27. Weighted-mean temperatures for 10 mm length intervals of alewives caught by all gear types from Pigeon Lake and Lake Michigan in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1977. Vertical lines represent ± 2 standard deviations.

months in Pigeon Lake was not wide, leaving alewives little freedom in selecting a favorable environmental temperature.

Other Considerations -- Catches of alewives at station L (6 m - n.) and C (6 m - s.) were statistically tested for differences between stations, months and diel period for each gear type. Differences between months were generally significant, while differences between stations and diel periods were not. For further details on statistical analyses refer to the STATISTICS section.

Alewives are the most important forage for salmonids in Lake Michigan. Stomach analyses of fish from this study showed that brown and lake trout, coho salmon and rainbow trout all fed on alewives (adults and YOY) extensively. In addition alewives were found in the stomach of one northern pike collected from Pigeon Lake, rainbow smelt were found to consume small alewives and we also noted adult alewives eating their own YOY (40 mm).

Summary -- During late spring, spawning alewives moved inshore to spawn and were present in both Lake Michigan and Pigeon Lake when sampling began in June. During June through September adults generally moved from 3 to 6 m during the day to the beach zone or into surface water at night. Spent individuals apparently left the inshore area soon after spawning. Adult alewives were essentially gone from the study area by October.

In Lake Michigan YOY first appeared in the sampling gear in July and were found primarily in the beach zone in approximately equal numbers day and night. A diurnal pattern of movement away from shore at night was generally apparent from August through November. Beginning in August larger YOY moved offshore and out of the study area. No YOY alewives were caught in Lake Michigan after November.

Adult alewives were spawning in Pigeon Lake during June; earlier spawning in Pigeon Lake than Lake Michigan was indicated by the presence of larvae and spent adult in Pigeon Lake, while few or none were seen in Lake Michigan catches. Fewer adults were caught after June in Pigeon Lake and none were caught after October.

A 35 mm YOY alewife was seined as early as June in Pigeon Lake. Higher concentrations of YOY were in Pigeon Lake than in Lake Michigan in July. A strong nocturnal offshore migration of alewives occurred in Pigeon Lake in July leading to increased entrainment. Very few YOY were caught after October.

YOY in Lake Michigan were caught at much warmer temperatures than adults, but in Pigeon Lake there was little difference. Mid-summer temperatures in Pigeon Lake outside the influence of Lake Michigan may deter spawning alewives from entering these areas. Alewives are important forage for the salmonids now inhabiting Lake Michigan.

Rainbow Smelt--

Introduction -- Rainbow smelt are an introduced species in the Great Lakes region. Smelt populations in Lake Michigan originated from a planting in Crystal Lake, Michigan in 1912 (Van Oosten 1937). Commercial production in Lake Michigan fluctuated widely during the period 1931-1974 with the largest annual catch 4.1×10^6 kg in 1958 (Jaiyen 1975). Decline of production during the period 1959-1965 resulted from reduced demand and low smelt populations (Wells and McLain 1973). In recent years smelt populations in Green Bay and along the western shore of Lake Michigan appeared to be higher than during the early and mid 1960's (Jaiyen 1975). In addition to commercial fishing, smelt also are caught during dipnet sportfishing at the time of their spawning runs (Scott and Crossman 1973).

Smelt feed mainly on *Mysis* and *Pontoporeia* and may be a food competitor of lake whitefish, lake herring and small lake trout which also prefer these crustaceans (Jaiyen 1975). Although smelt sometimes consume fish, there is little evidence that they are highly piscivorous (Scott and Crossman 1973); however, Gordon (1961) found they were cannibalistic during some times of the year. Rainbow smelt are forage for a number of species including lake trout, burbot, walleye and yellow perch (Scott and Crossman 1973).

Smelt were one of the most numerous fish collected during this study, being found mostly in Lake Michigan. Only a few specimens were collected from Pigeon Lake. Trawls generally captured more smelt than were captured in seines or gill nets.

Seasonal Distribution -- Rainbow smelt usually remain in deep water over winter. In eastern Lake Michigan, adult smelt were found mostly from the 12 to 45 m depths in February and seemed to move closer to shore in March when most were caught in water between 12 and 30 m (Wells 1968). In Lake Michigan, the spawning season usually started in April (Becker 1976, Jude et al. 1975) when water temperature reached 10 C. The spawning run may last up to 3 wks, but the peak rarely lasts more than 1 wk (Scott and Crossman 1973). Spawning usually takes place at night in streams or the shallow waters of lakes (Rupp 1965) and the spawners return to offshore areas at daybreak (Van Oosten 1940).

In 1977 we did not sample during the spawning season. Gonad data (Table 25) and occurrence of YOY in our July trawl catches (Appendix 5), however, suggested that spawning probably took place in our study area in April or May. Catches of numerous ripe-running smelt in the inshore waters of Lake Michigan during latter April and early May 1978 confirmed our inference on spawning in 1977.

TABLE 25. Monthly gonad conditions of smelt caught in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Males	Slight development	10	13	14	60	1		
	Mod. development	3	6	8	28	1		
	Well developed	1		1	5			1
	Ripe-running							
	Spent	4						
Females	Slight development		5	10	50			
	Mod. development	1			1			
	Well developed							
	Ripe-running							
	Spent							
	Absorbing							
Immature		349	178	329	369	171	61	403
Unable to distinguish		2	21	36	29			

June -- A small number of smelt were caught by seine at the three beach stations in Lake Michigan (Fig. 28). Smelt were not captured in day gill nets. Due to bad weather gill nets were not set at night. Trawling yielded a modest catch of smelt (Fig. 29)

Adult smelt (mostly over 120 mm) rarely entered the beach zone during June as none were caught by seine. During the day, adult smelt over 120 mm in total length were distributed from the 6 to 21 m depth contour and were most common in the 6-12 m zone (Fig. 30). At night smelt occurred at 6 and 9 m depths. Adult smelt usually migrate to deep water shortly after spawning. In southeastern Lake Michigan, Wells (1968), found that smelt moved to the 6-18 m depths by early May and reached the 36 m contour by the end of May. Low catch of large smelt in the study area suggested that only a small adult population remained inshore in June, probably in response to upwellings as adult smelt preferred cold water and remain offshore during warm summer months.

Adult smelt are known to exhibit a diel vertical migration. Ferguson (1965) reported that during the day smelt were concentrated near the bottom while at night they were dispersed in the upper layers of the water column. In our study area adult smelt probably showed a similar diel distribution as more were caught by the bottom trawl during

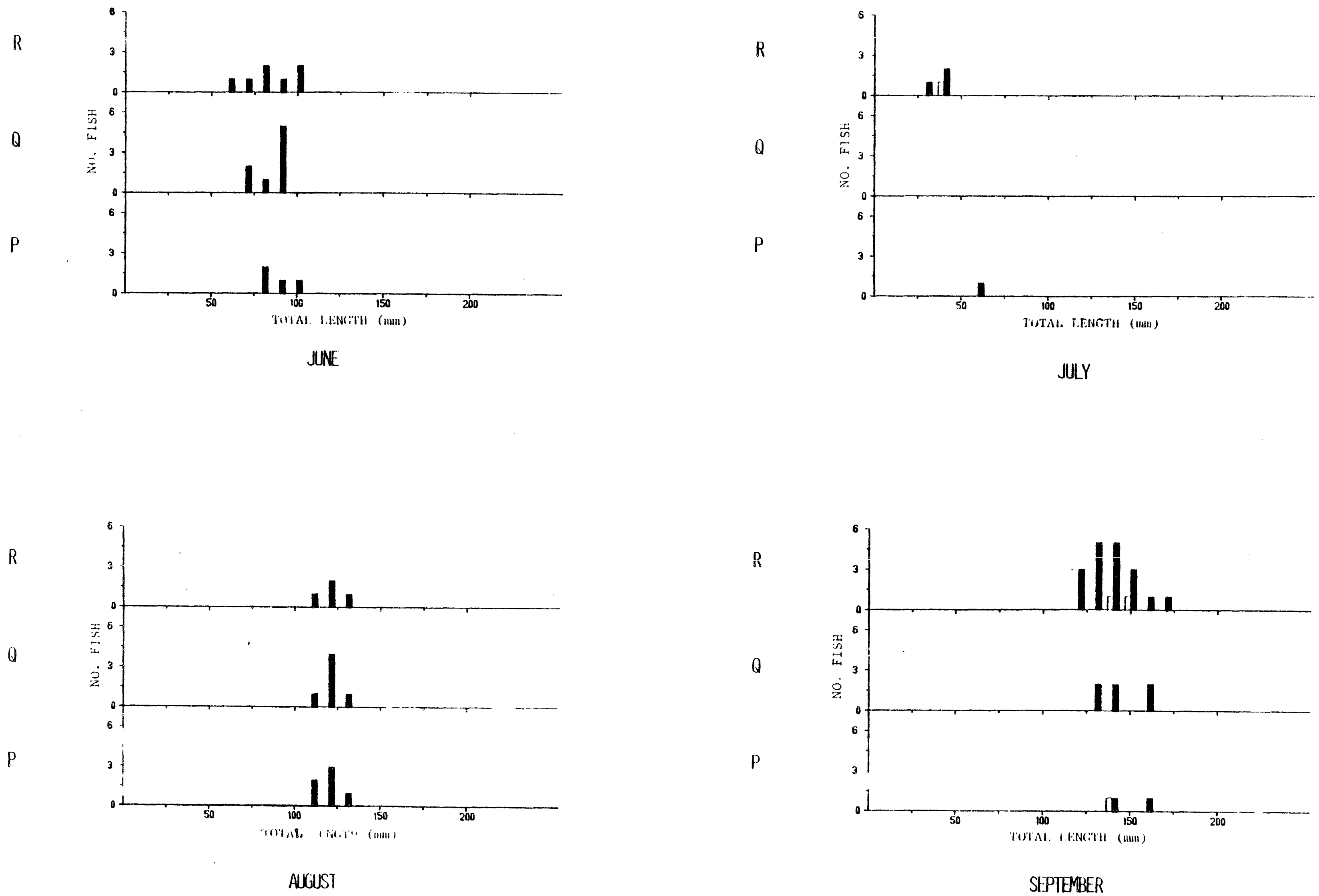


FIG. 28. Length-frequency histograms for rainbow smelt caught in duplicate seine hauls June to November 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.

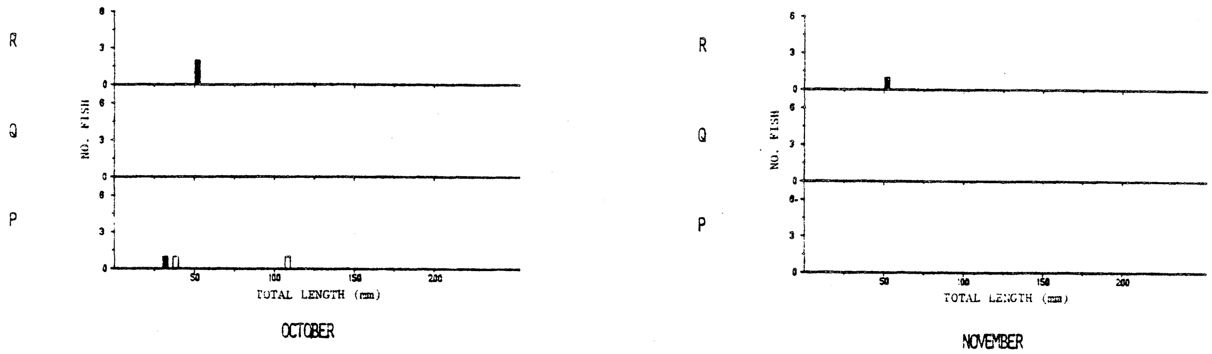


FIG. 28. (Continued)

the day than at night (Fig. 29), clearly not net avoidance.

Yearlings collected in June ranged from 50-120 mm in total length and had a modal length of approximately 80 mm (Appendix 4). Several specimens were caught by night seine (Fig. 28), but most were taken by day and night trawl (Fig. 30). Night distribution of yearlings extended from the beach zone to the 21 m depth with highest concentrations at the 6 m contour. During the day they ranged from 6 to 21 m, being most common at 9 m.

Yearlings seemed to move close to shore and into the beach zone at night, but remained in deep water during the day. Similar nocturnal movements to the shallow areas appeared to also occur during other summer months (Figs. 28 and 29). These data were in agreement with Emery (1973) who observed a large number of smelt of all sizes in shallow areas during night SCUBA dives in Little Dunk's Bay in Georgian Bay, Lake Huron. Comparisons of day vs. night catches of yearling smelt suggest that they, like adults, may exhibit diel vertical migration (Fig. 30).

The June catch of yearlings was the highest of all monthly catches of this size class. Presence of modest numbers of yearlings near the Cook Plant, in southeastern Lake Michigan during April and May (Jude et. al. 1975) suggests that they also may occur near the Campbell Plant at this time.

July -- Catch of adult smelt declined sharply in July (Appendix 4). Small numbers of large smelt were trawled during the day between 12-18 m (Fig. 30). Three adults were caught in day bottom gill nets (Figs. 31 and 32) and one in a night surface gill net at the 6 m contour (Fig. 33). Adult smelt were not collected by seine. Most adult smelt were probably in deeper cooler water by this time. In summer, they were found mostly from 9 to 30 m in eastern Lake Michigan (Wells 1968) and in slightly deeper water (16-90m) in northern Lake Michigan (Jaiyen 1975). In Lake Erie however, large numbers of yearlings were found in water 6-9

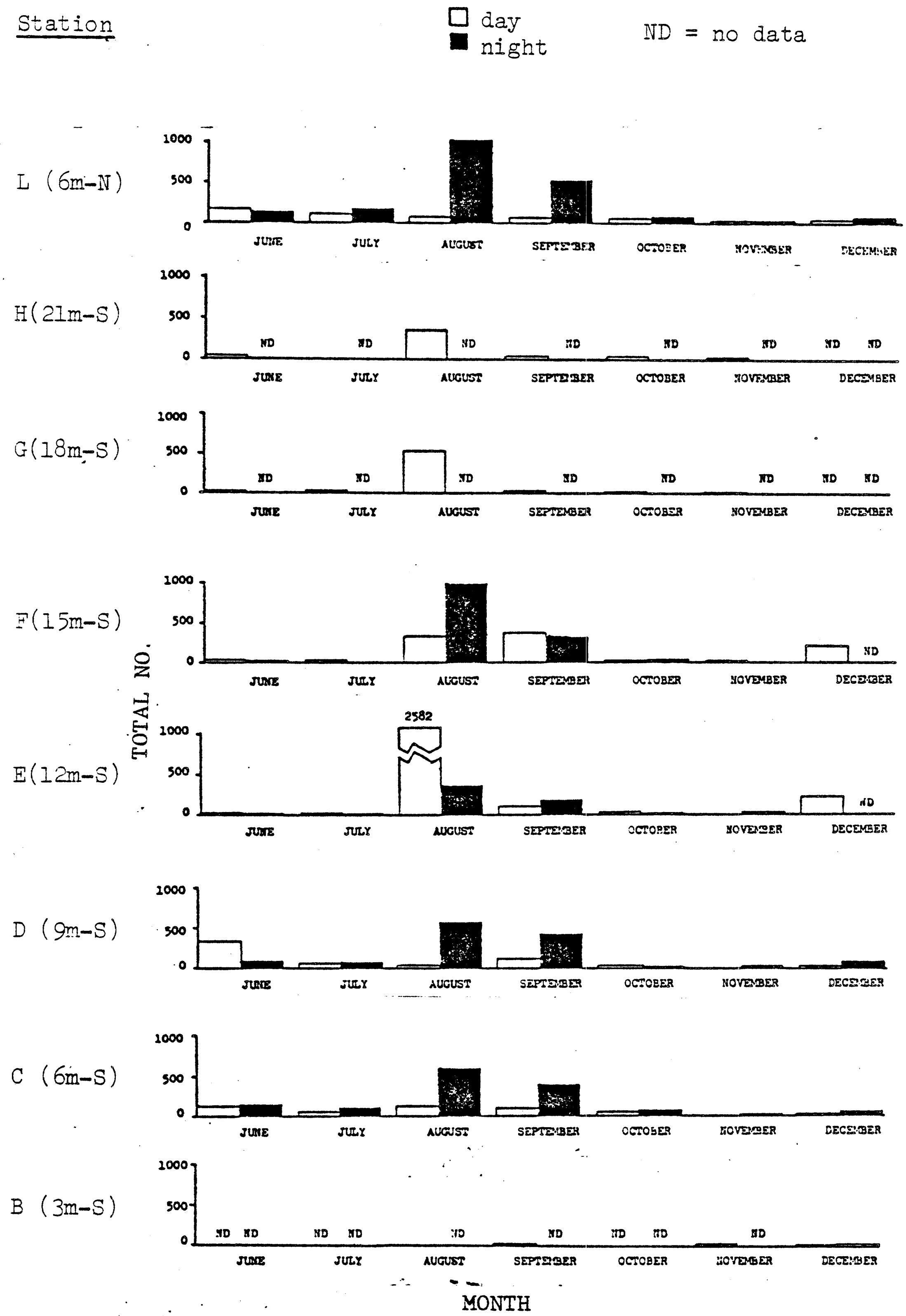


FIG. 29. Total number of rainbow smelt caught in bottom trawls fished during day and night once per month June through December 1977 in eastern Lake Michigan in the vicinity of the J. H. Campbell Power Plant.

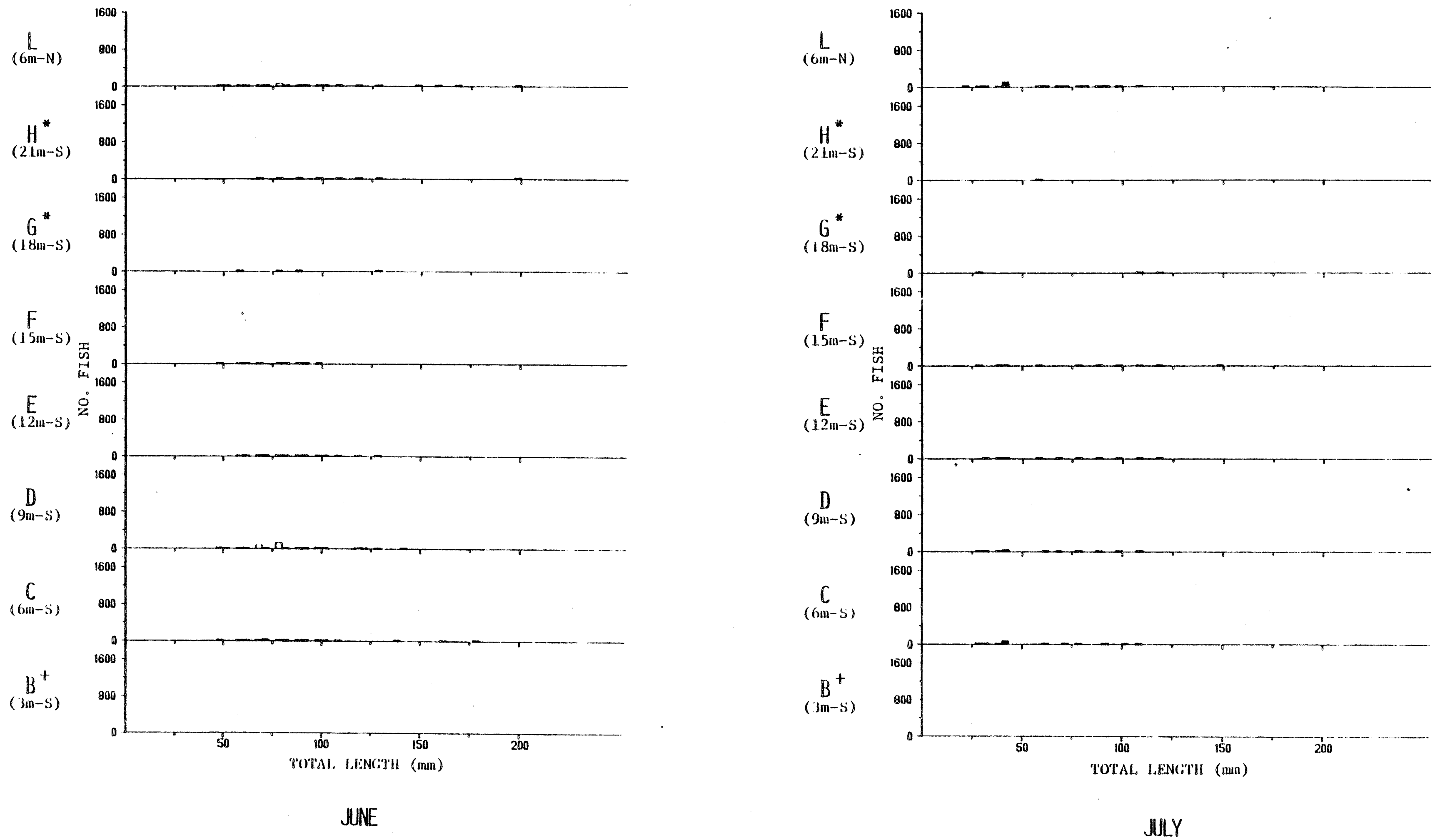


FIG. 30. Length-frequency histograms for rainbow smelt caught in duplicate trawl hauls during June to December 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.
* = No night sampling performed.
+ = No sampling performed.

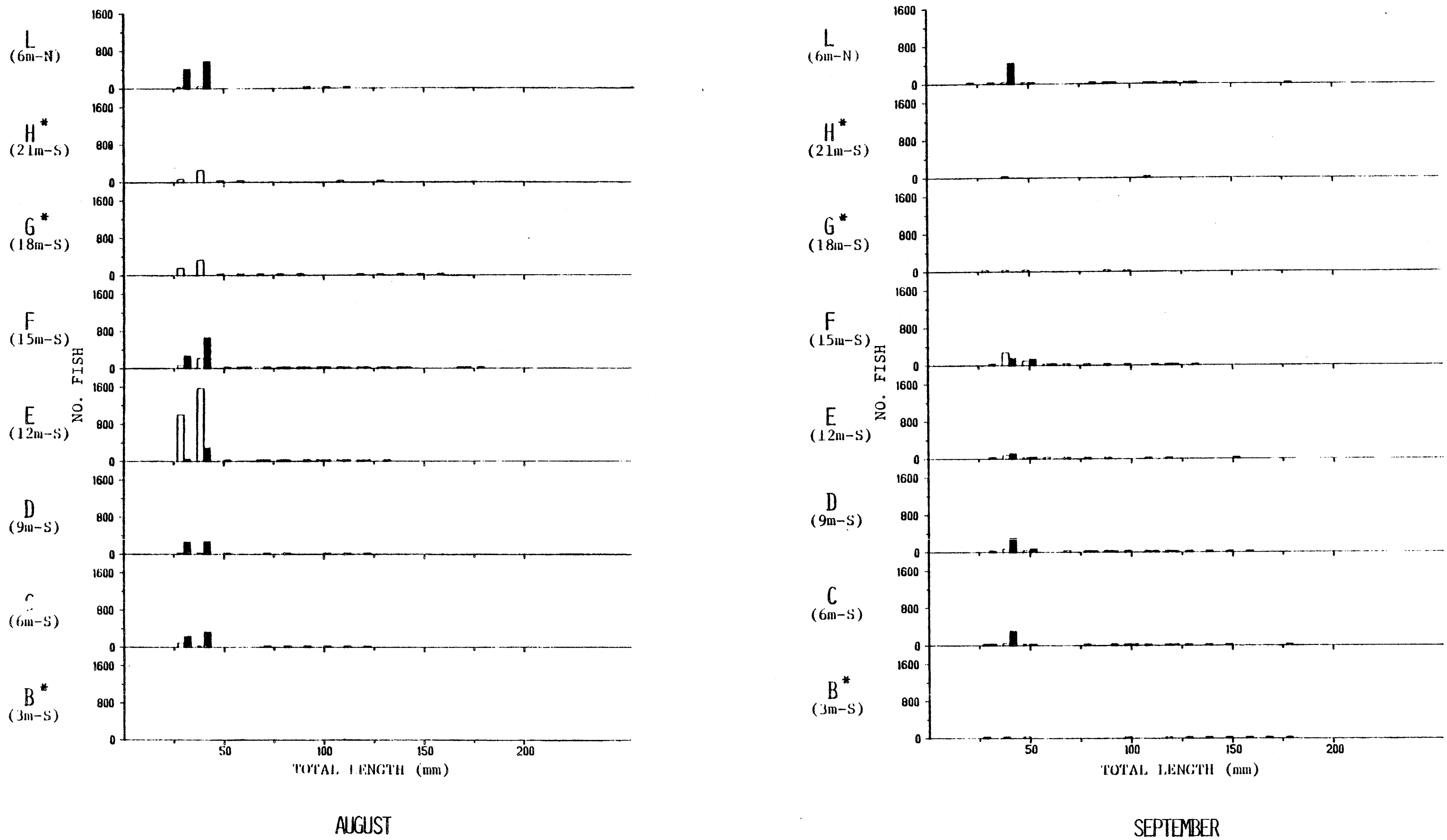


FIG. 30. (Continued)

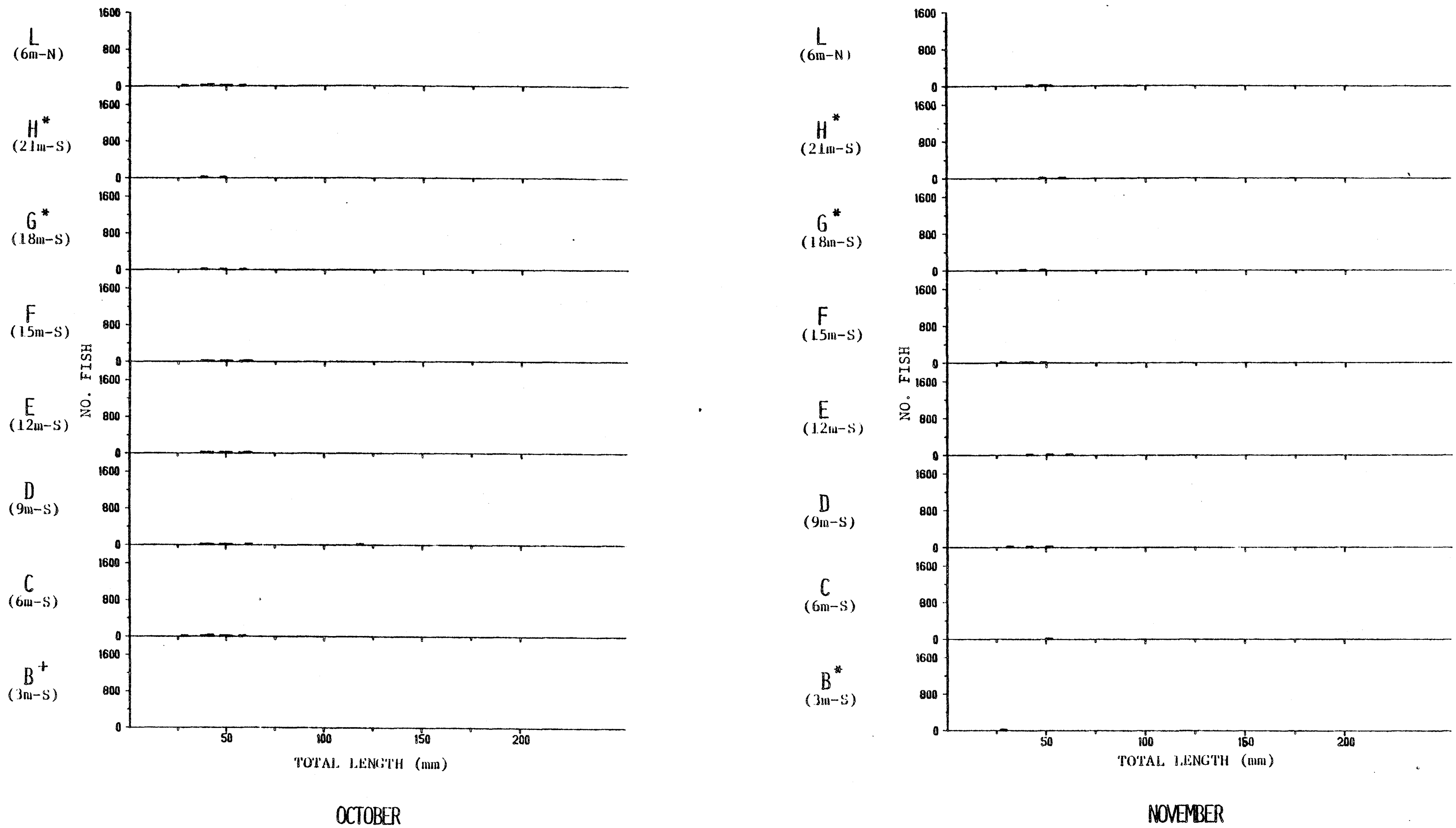


FIG. 30. (Continued)

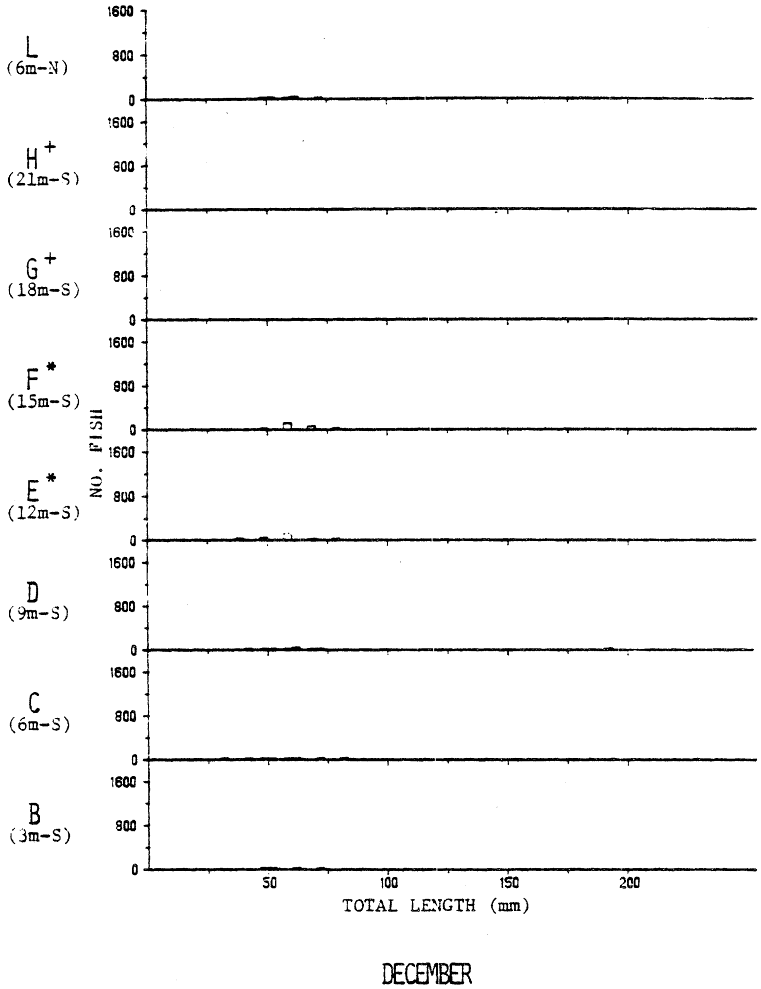


FIG. 30. (Continued)

m in July (Ferguson 1965).

A modest number of YOY smelt from 25 to 40 mm in total length first appeared in July seine and trawl catches (Figs. 28 and 30). At night they were distributed from the beach zone to the 15 m contour and were most abundant at 6 and 9 m. During the day they were caught in small numbers between the 6-18 m depths. More YOY were caught at night than during the day probably as a result of their high concentration at 6 and 9 m at night and their dispersal into deeper water during the day.

August -- In August adult smelt were relatively scarce in the study area. A small number were trawled between 3 and 18 m during both day and night (Fig. 30) and a few were caught by bottom gill nets at 3, 6, 9 and 12 m (Fig. 32).

Yearlings, ranging from 70 to approximately 120 mm, were caught in

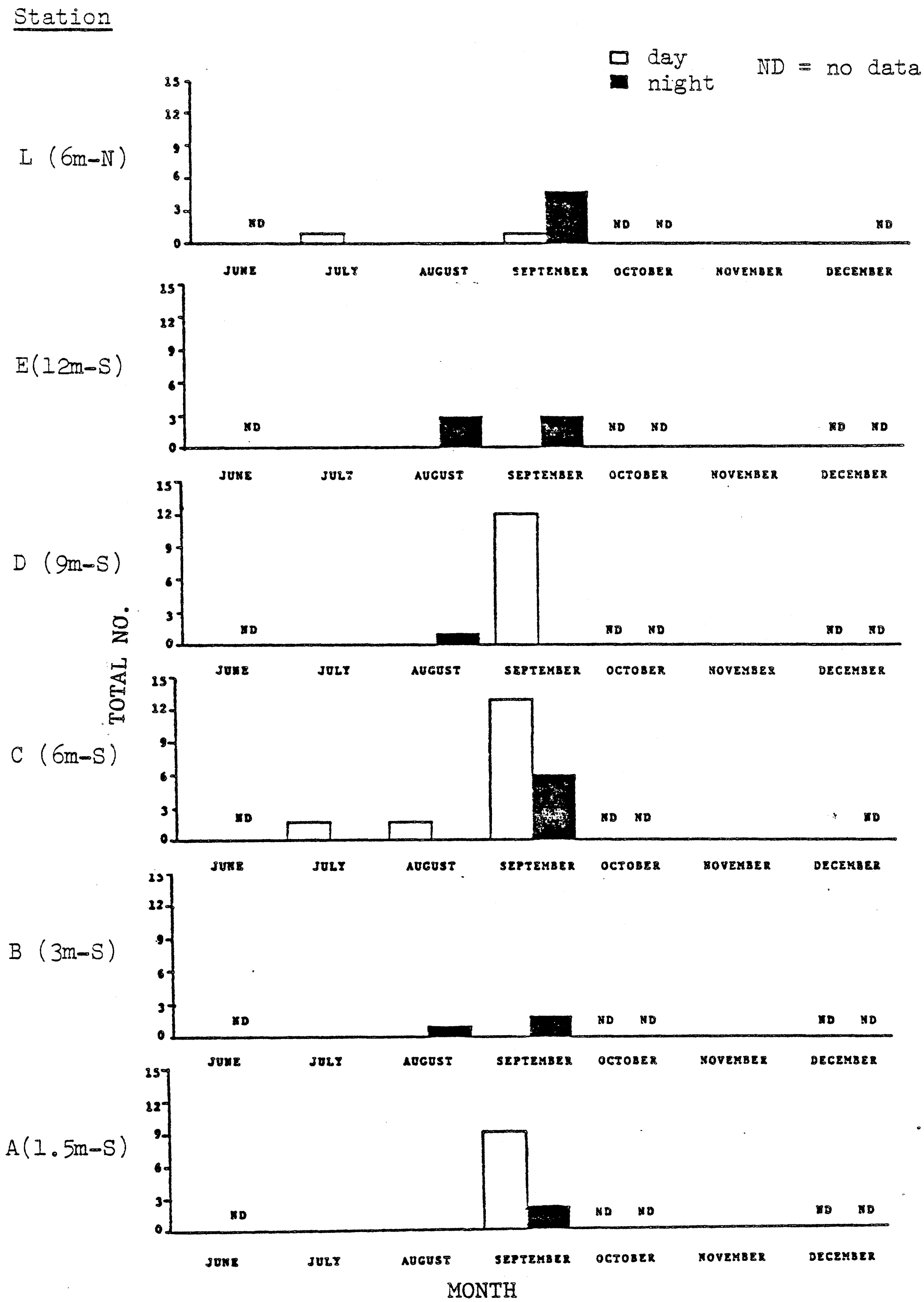
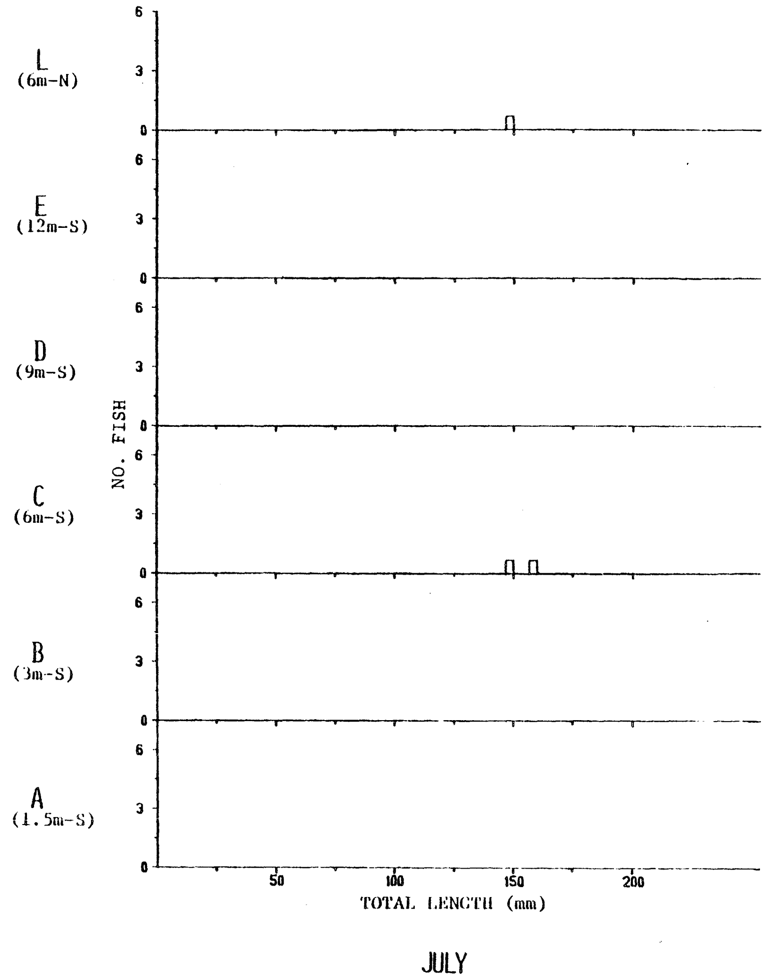


FIG. 31. Total number of rainbow smelt caught in bottom gill nets fished during day and night once per month June through December 1977 in eastern Lake Michigan in the vicinity of the J. H. Campbell Power Plant.



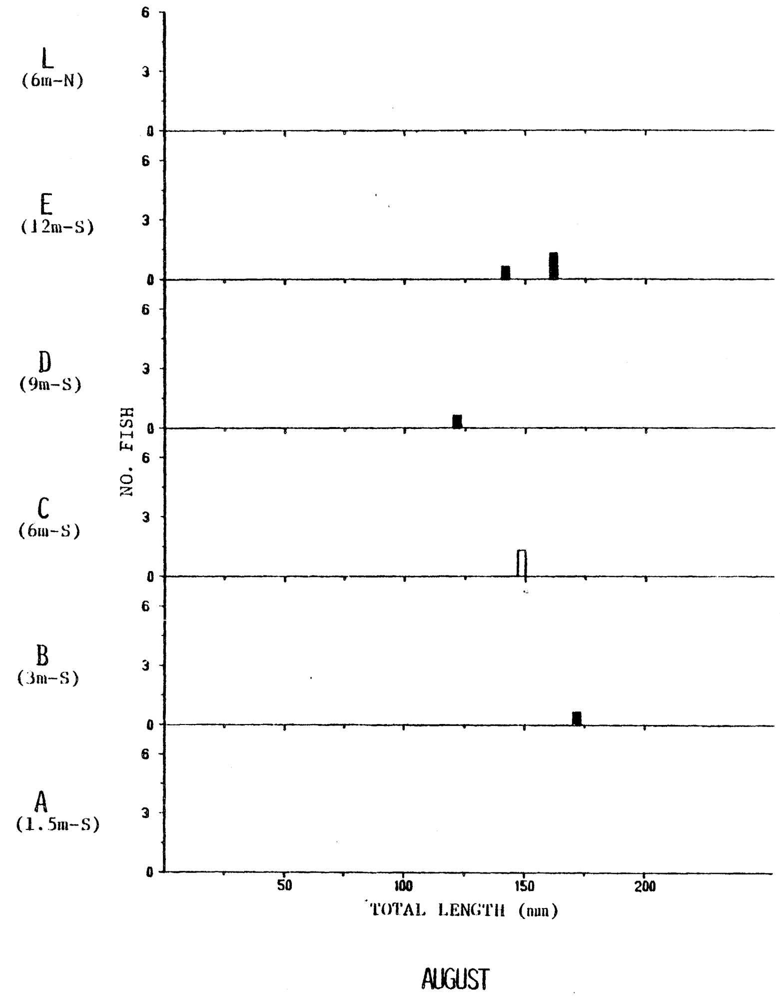


FIG. 32. Length-frequency histograms for rainbow smelt caught in duplicate bottom gill nets during July to September 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan. □ = day ■ = night.

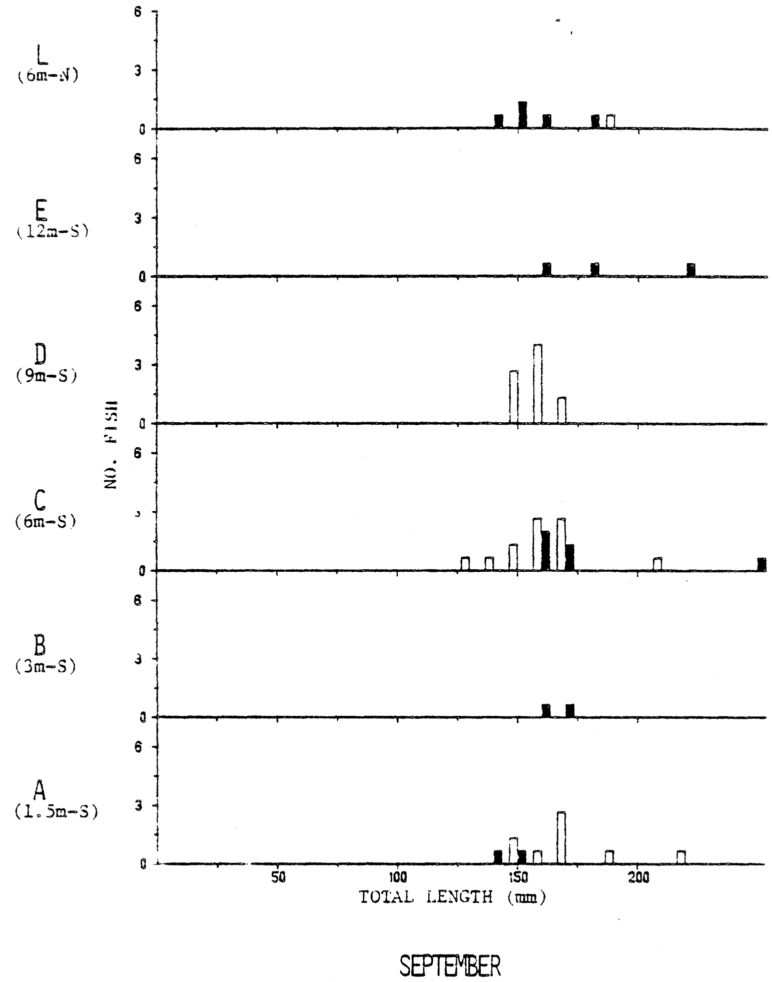


FIG. 32. (Continued)

smaller numbers during August than in July (Appendix 4). At night, several specimens were collected by trawl in waters up to 15 m deep (Fig. 30) and by beach seine (Fig. 28). They seemed to be evenly distributed in this zone at night. During the day yearlings were caught only from 12 to 21 m and were most common from 15 to 18 m. Compared to previous months, their day range appeared to be steadily shifting toward deeper water. A slightly higher number of yearlings were caught at night than during the day.

Largest catches of YOY during 1977 were made in August (Appendix 4). By this time YOY smelt ranged from 30 to 45 mm in total length with a modal length of approximately 40 mm. In the vicinity of the D. C. Cook Plant, southeastern Lake Michigan peak catch of YOY approximately the same size also occurred in August 1973 (Jude et al. 1975). This supported our previously asserted hypothesis that smelt in our study

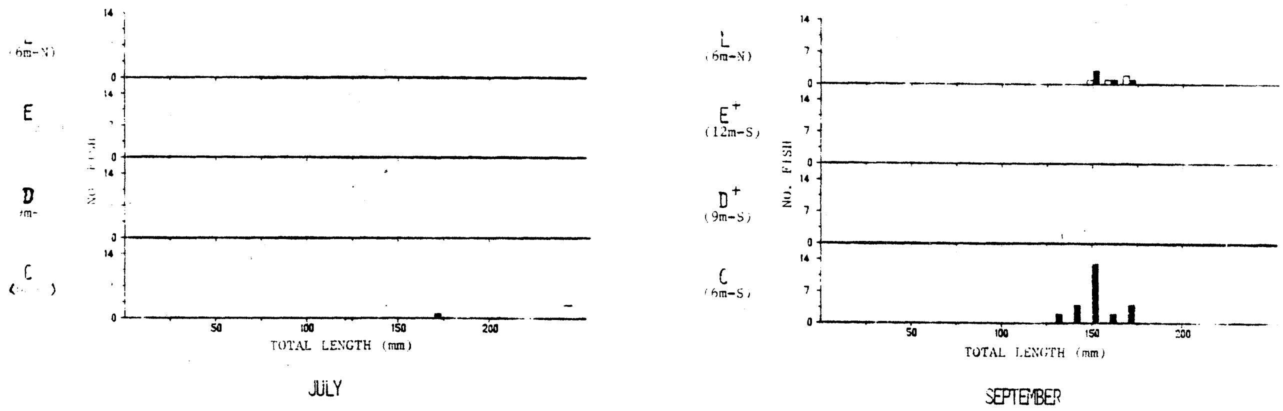


FIG. 33. Length-frequency histograms for smelt caught in duplicate surface gill nets during July to September 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan. □ = day ■ = night.
+ = No sampling performed.

area spawned at approximately the same time as those near the Cook Plant.

YOY were caught only by trawl during August, suggesting that smelt this size rarely entered the beach zone. During the day YOY were found from 6 to 21 m and were most abundant at the 12 m contour (Fig. 30). At night YOY were distributed from 6 to 15 m with the highest concentration at 15 m. The large YOY catch at 15 m suggested that YOY smelt probably range into deeper water at night. Night trawling was, however, not performed at 18 and 21 m in August.

September -- In September catch of adult smelt was higher than any monthly catch during the study (Appendix 4). Adult smelt were present in the area due to an upwelling of cold water (mostly from 5.1 to 10.6 C). They were caught in all our fishing gear and appeared to be distributed from the beach zone to 15 m or deeper water (Fig. 29). The September catch provided strong evidence of diel vertical migration by adult smelt. Surface gill nets at 6 m captured several large smelt at night and very few during the day (Fig. 33). Bottom gill nets and trawls, on the other hand, captured more adult fish during the day than at night (Figs. 32 and Appendix 5).

Yearling smelt populations in the study area, as revealed by our catch, decreased slightly from the level observed in August (Appendix 4). Cold inshore water may have delayed their retreat to deeper water. Yearlings were caught mostly by trawl (Fig. 30); seines and gill nets captured only a few large yearlings (Figs. 28 and 32). During the day they were found at all depths from the beach zone to 21 m. At night their distribution extended from the beach zone to at least 15 m (no trawling was performed at 18 and 21 m).

Catches of YOY continued to decline in October and November (Appendix 4) as most YOY had probably moved to deeper water by this time. More YOY were caught at night than during the day in these 2 months. In eastern Lake Michigan, Wells (1968) reported catching appreciable numbers of YOY smelt in water 18 to 36 m in October and November.

In December YOY catch increased considerably over the previous 2 months (Appendix 4). During the day they were caught by trawl from 3 to 15 m (no trawling was performed at stations deeper than 15 m during the day), and were most common at the 12 and 15 m depths (Fig. 30). At night YOY occurred from 3 to 9 m (no trawling was performed in water deeper than 9 m at night) with the highest concentration at 6 and 9 m. In December more YOY were caught during the day than at night probably because night trawling was performed at fewer stations than during the day. Due to bad weather, no other fishing gear were used. The large catch of YOY in the study area suggested that they may periodically return to shallow water in late fall. These YOY were actively feeding during this month as 94% had food in their stomachs.

Temperature-Catch Relationship -- Smelt usually inhabit in cold water. Various size classes, however, have been observed to show different temperature preferences. Ferguson (1965) indicated that adult smelt preferred water temperatures around 6.1 C. Jude et al. (1975) reported catching most adult smelt at water temperatures of 6-8 C and most YOY and yearlings at 12-14 C. In our study area yearlings were caught most often at temperatures ranging from 4-12 C and adults at 6-14 C. These observations agreed with Wells (1968) who found most smelt in water temperatures of 6-14 C.

YOY less than 70 mm appeared to tolerate relatively warm water and occurred in waters with a wider temperature range than did larger smelt (Fig. 34). In our study area most YOY were caught in water from 6 to 20 C. In Lake Erie, Ferguson (1965) found large numbers of YOY smelt but very few adults at a water temperature of 21 C. In another study on Lake Erie smelt, MacCallum and Regier (1970) received larger catches of YOY in 18 C water.

Based on data from several Maine lakes, Rupp (1959) concluded that there was a marked inconsistency in the timing of smelt spawning runs with respect to water temperature. Both water temperature and weather conditions may influence the smelt spawning run (Van Oosten 1940). In southeastern Lake Michigan, Jude et al. (1975) observed peak spawning in April when water temperatures ranged from 8 to 10 C.

Other Considerations -- Although rainbow smelt occurred in appreciable numbers in several inland lakes, there appeared to be no resident smelt population in Pigeon Lake. Only seven specimens,

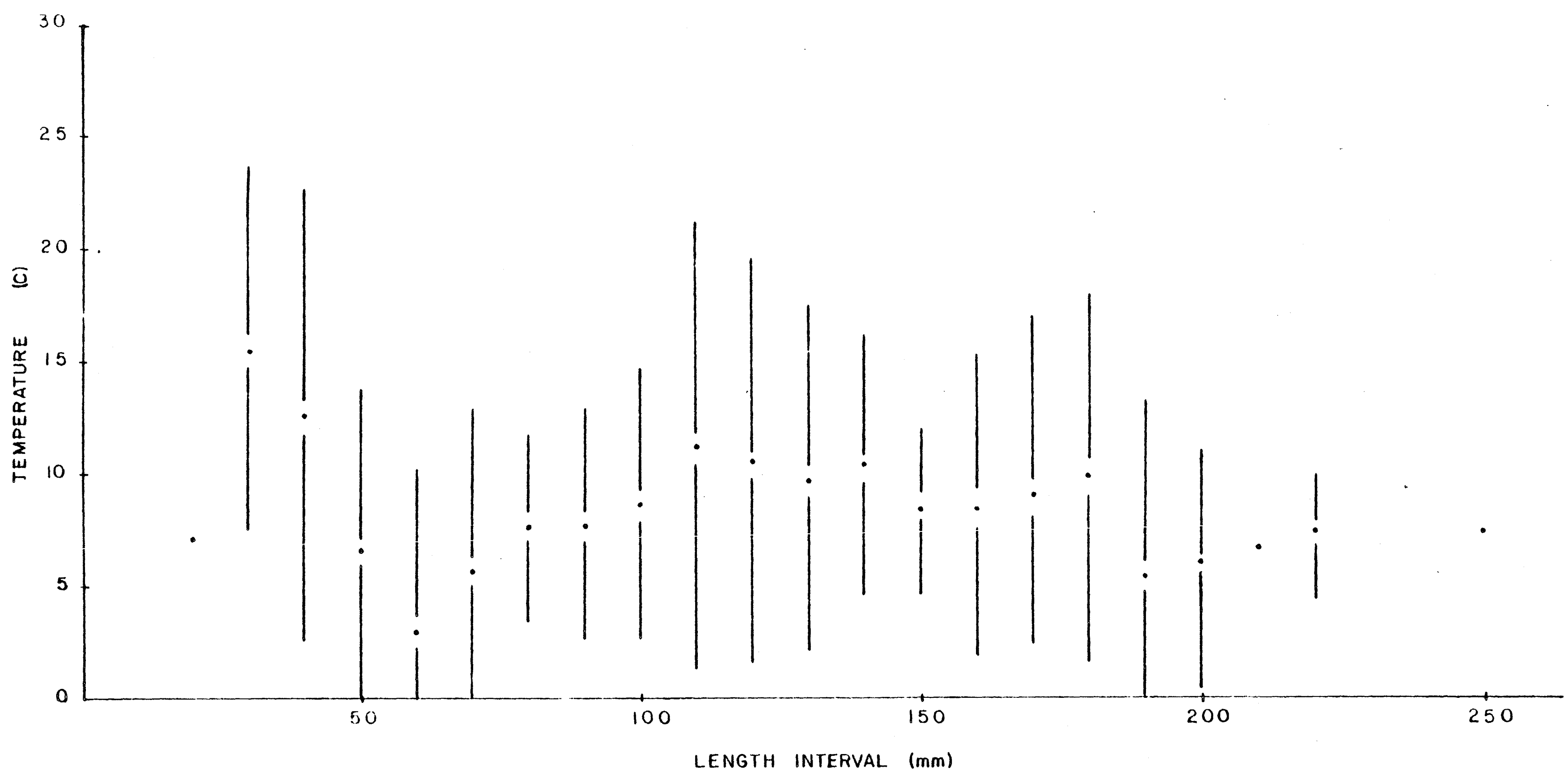


FIG. 34. Weighted-mean temperatures for 10 mm length intervals of rainbow smelt caught by all gear types from Lake Michigan in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1977. Vertical lines represent ± 2 standard deviations.

including one, 28 mm long YOY caught at beach station T (influenced by Pigeon River), five yearlings and one adult were collected from Pigeon Lake. All these smelt probably immigrated from Lake Michigan.

As mentioned earlier, spawning of smelt often takes place in tributary streams. Preliminary observations on the adult fish catch in April and May 1978 and 1977 larval fish data showed no evidence of extensive smelt spawning in Pigeon Lake. Occurrence of a YOY at beach station T (influenced by Pigeon River), however, suggested that some incidental spawning may occur in Pigeon Lake or Pigeon River.

YOY from the April-May spawning reached a modal length of 40 mm in August, 50 mm in October and 60 mm in December (Appendix 4). A similar growth rate of YOY smelt was observed in Gull Lake, Michigan (Burbidge 1969). In southeastern Lake Michigan, YOY appeared to grow slightly faster, reaching a modal length of 40 mm in August, 45 mm in September and 54 mm in October (Jude et al. 1975). A much faster growth of YOY smelt was reported from different areas in western Lake Michigan. The average calculated length of smelt at the end of the first year of life was 86.7 and 84 mm for males and females collected at Zion, Illinois and 83 and 82.5 mm for males and females collected at Two Rivers, Wisconsin (Robinson 1973). Yearlings in our study area attained a modal length of 80 mm in June. This size was comparable to the modal length of 65 mm reached in September by yearlings near the Cook Plant (Jude et al. 1975).

Rainbow smelt were reported to serve as food for predatory fishes in Lake Michigan. They occurred in 28% of the stomachs of immature lake trout collected from this lake (Wright 1968). In our study area, smelt were occasionally found in stomachs of lake trout and brown trout. They appeared, however, to be far less important than alewives as forage for these predatory fish.

Catches of smelt at station L (6 m - s.) and at station C (6 m - reference) appeared to be similar throughout the study period (see STATISTICS). Apparently the present thermal discharge did not affect the distribution of smelt around the 6 m station during the times of our sampling.

<u>Summary</u> -- Rainbow smelt were the second most abundant species caught in Lake Michigan. There appeared to be no resident smelt population in Pigeon Lake where only a few specimens were collected. Spawning probably took place during April and early May in the shallow areas of Lake Michigan. Pigeon Lake was apparently not utilized as a spawning ground by smelt.

YOY smelt occurred mostly between 6 and 18 m and were first caught in July by trawls. A few were also taken in seines. YOY catches peaked in August, then declined through summer and fall probably as a result of

offshore movements. High catches of YOY in December suggested that they may periodically return to inshore waters in late fall.

Yearling smelt were usually found between 6 and 15 m. Monthly catches were highest in June and declined substantially in July and the rest of summer as yearlings moved offshore. They were relatively scarce in the study area during fall.

Adult smelt were caught in small numbers between 6 and 15 m. These low catches may be due to the small adult population in the inshore waters during summer as most large smelt migrated offshore shortly after spawning. Upwelling of cold water may, however, induce them to return to shallow water during summer. Like yearlings, adult smelt rarely occurred in the inshore areas during fall.

Adult and yearlings were caught mostly in water temperatures from 6-14 C. Most YOY occurred at water temperatures of 6-20 C. Adults and yearlings exhibited diel vertical migration, being found mostly near the bottom during the day and near the surface at night.

Spottail Shiner--

Introduction -- Spottail shiners are minnows found in shallow areas of large lakes and rivers; in North America they are distributed from portions of Canada south to the United States, from Georgia in the east to Iowa and Missouri in the west (Scott and Crossman 1973). They are found in all the Great Lakes and many of their tributaries (Hubbs and Lagler 1964).

In several midwestern lakes, spottail shiners serve as an important forage and bait species. They are the main item in the diet of walleyes in Lake Erie (Parsons 1971) and Lower Red Lake, Minnesota (Smith and Kramer 1964). Spottail shiners are also utilized as food by smallmouth bass (Surber 1939) and northern pike (Hunt and Carbine 1951). Although they are abundant in Lake Michigan, spottail shiners appear to play only a minor role as forage for larger predatory fishes (Wells and House 1974, Jude et al. 1975, Jude et al. 1979).

Comprehensive studies on the life history of this species are rare. The first research work on the biology of spottail shiners in Lake Michigan was an investigation on their age, growth and food habits conducted in Little Bay de Noc (Basch 1968). From the results of experimental trawling, Wells (1968) described their seasonal depth distribution in the southeastern part of the lake. More recent studies on spottail shiner biology, life history and distribution were reported by Wells and House (1974) and Jude et al. (1975) in southeastern Lake Michigan. More research is needed to determine the ecological

significance of this minnow in the inshore fish community of Lake Michigan.

Spottail shiners were numerically the third most abundant fish collected in our study during June to December 1977. In Lake Michigan 7883 spottails (10% of the total fish catch, Table 13) were collected by all gear; while in Pigeon Lake 4547 spottails were caught (22% of the total fish catch, Table 14). Although different fishing gear select for certain species and sizes of fish, the high number of spottails observed illustrates the heavy utilization of inshore waters of Lake Michigan and its tributaries during summer and early fall. Spottail shiners (like several other fish species in Lake Michigan; e.g., alewife, trout-perch, yellow perch) overwinter in deep water, enter the inshore waters in spring when water temperatures are rising, concentrate in summer to spawn, then return to deeper water in fall (more discussion of this will follow). Jude et al. (1975) and Jude et al. (1979) found similar seasonal movements of spottail shiners off the Cook Plant, southeastern Lake Michigan (108 km south of the Campbell Plant). In Lake Michigan during the Campbell Plant study most spottails (83.8% of the total spottail catch) were collected by seining, while trawling contributed 8.7% and gill nets 7.5% (Tables 15, 17, and 18). This high proportion of the catch from seining resulted from the concentration of spottails along the beaches in summer and early fall. Seining also supplied the vast majority (99.9%) of spottails collected in Pigeon Lake (Tables 19 and 20). Although trawling was not performed in Pigeon Lake, seine catches are indicative of the summer and fall concentrations of YOY spottails in the lake shallows. Small fish are also more vulnerable to seining because seine mesh size (bar measure 0.5 cm) was the smallest of any mesh in the gear we use. Our catch data showed spottails to be a benthic minnow as only one spottail was caught in surface gill nets.

<u>Seasonal Distribution</u> -- Seasonal distribution of adult and juvenile spottails was analyzed by discussing monthly catches. Because sampling was initiated in June, only summer, fall and early winter catches will be treated. Spottail distribution in southern Lake Michigan during winter and spring can be inferred from data in Jude et al. (1975) and Jude et al. (1979). The following is a brief summary of their winter-spring findings.

During winter months (December, January and February) the bulk of the spottail shiner population in southeastern Lake Michigan was in water deeper than 9 m. There appeared to be some movement of spottails to 9 and 6 m during winter. Spottail shiners (162 fish) were impinged at the Campbell Plant during December 1974, and January, February 1975 (Consumers Power Company 1975), also indicating that some spottails remain inshore or in Pigeon Lake during the winter. Wells (1968) reported that spottails were most abundant between 18 and 27 m during February 1964 in southeastern Lake Michigan. Jude et al. (1975) found

the spring inshore migration to 9 and 6 m began in March and continued into April. By May most of the population had reached 6 and 9 m. We believe a similar winter-spring distribution of spottails occurs in the Campbell Plant vicinity. Discussion of Campbell Plant data can now begin with catches in June.

June -- Spottails were caught in Lake Michigan in moderate numbers (559) in June. Night seining at station R (n. discharge) produced most of these fish (Fig. 35). At beach stations Q (s. discharge) and P (s. reference) some spottails were caught during night seining, but in much lower numbers. This spatial difference may have been caused by the plant's discharge warming the water at station R. Water temperatures during night seining in June were 10.6 C at R, 8.0 at Q and 9.5 at P. Wells (1968) and Jude et al. (1979) have indicated that spottails preferred warmer waters in Lake Michigan. In contrast to high night seine catches, only one spottail was caught in day seines (Appendix 5). All sizes of yearling and adult spottails (40-140 mm) were caught in seine hauls, with the majority being in the 90 to 130 mm range (Fig. 36).

While seining indicated spottails were in the shallowest depths at night, gillnetting and trawling at deeper stations in June revealed few fish present. Although all trawl catches were low compared to seine catches, highest trawl catches occurred during the night at 6 m (Fig. 37). Some spottails were trawled during the night at 9 m (four fish) and 12 m (three fish), but no spottails were found at 15 m. During the day spottails were only trawled at 6 m, although there was an incidental day catch of three fish at 21 m (Fig. 37). Like seine catches, all sizes of yearling and adult spottails were caught during June trawling with the majority being adults from 100-120 mm (Fig. 38).

The only spottails caught by bottom gill nets in June were at 1.5 m (Fig. 39). Night gill nets were not set at any depth in Lake Michigan during June due to weather problems. Size range of gillnetted spottails was 110-130 mm, except for one fish in the 40 mm size group (Fig. 40).

High concentrations of adult spottails in June at night were probably the result of spawning activities. Gonad development data indicated most spawning in Lake Michigan occurred in June and July (Table 26). Our plankton net catches of spottail larvae in Lake Michigan were highest in late July; also some larvae were caught in early July (see FISH LARVAE AND ENTRAINMENT STUDY - Spottail Shiner). These larvae also indicated a June and July spawning period. Jude et al. (1979) at the Cook plant also found that spottails during 1973 and 1974 spawned in June and July. In addition, Wells and House (1974) found that spottails spawned in late June and July 1964 in southeastern Lake Michigan (off Saugatuck, Michigan). Fish were at depths from nearshore to 9 m during the spawning season and spawning was heaviest in the shallow portion of the depth range.

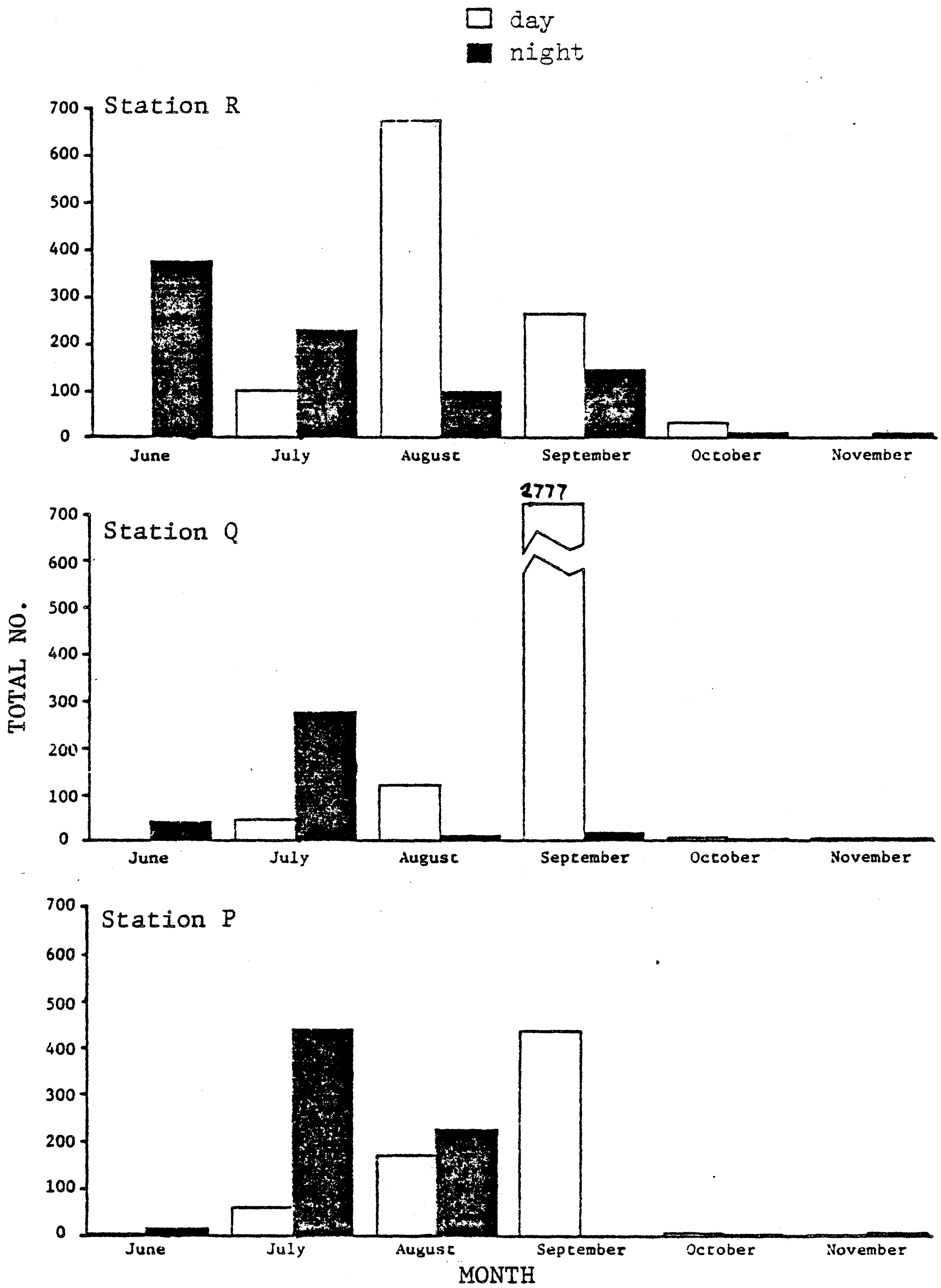


FIG. 35. Total number of spottail shiner caught in duplicate seine hauls in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, June - November 1977.

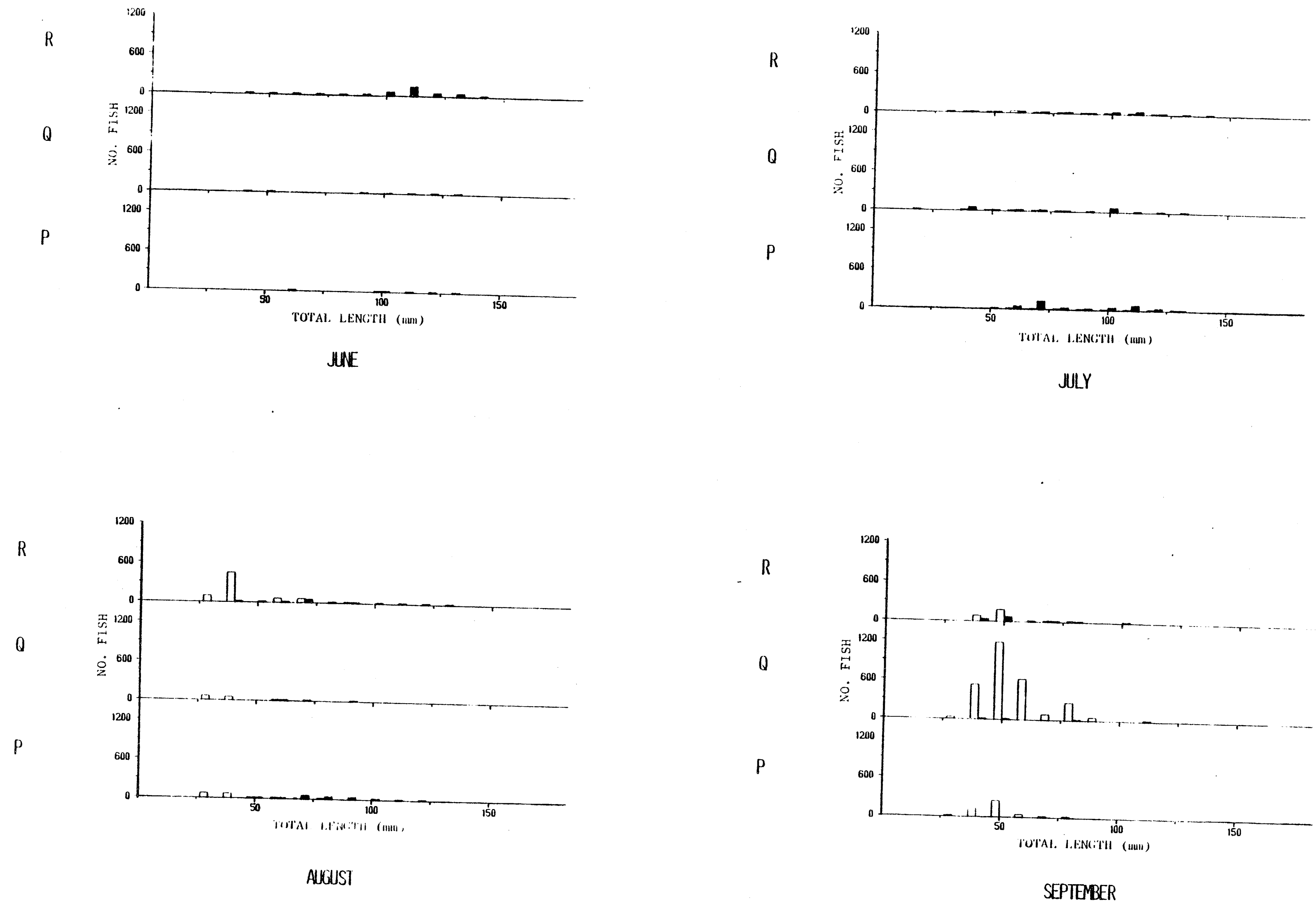


FIG. 36. Length-frequency histograms for spottail shiner caught in duplicate seine hauls during June to November 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan. □ = day ■ = night.

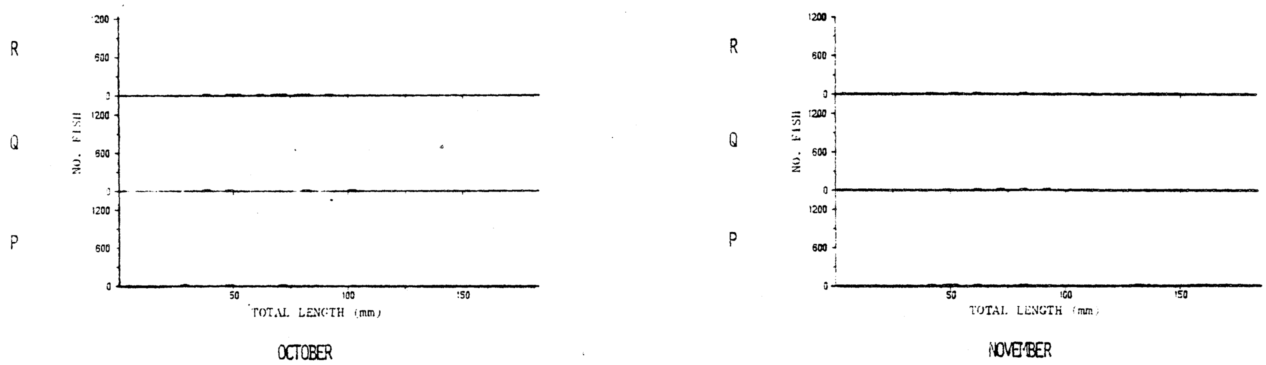


FIG. 36. (continued)

While we caught few spottail larvae in Lake Michigan during June, moderate numbers were caught in early and late June in Pigeon Lake. This early occurrence of larvae causes us to speculate (because no sampling occurred in May) that spottails spawned in Pigeon Lake during May. No adult spottails were caught in Pigeon Lake during June and only five were collected from July to December (Appendix 4). Earlier spawning in Pigeon Lake than in Lake Michigan may have been the result of warmer spring water temperatures available in shallow Pigeon Lake.

July -- In Lake Michigan twice as many spottails were caught in July (1107 fish) compared to June (559 fish). Most of the July Lake Michigan catch came from seines, 97%, while gill nets contributed 3%. No spottails were trawled in July. As in June, spottails caught in Lake Michigan during July came mostly from night seine hauls. July night seine hauls at station P (s. reference) contained the most fish, but moderate numbers were also caught at Q (s. discharge) and R (n. discharge) (Fig. 35).

Water temperature was the highest at beach station Q (20.0 C) compared with R (17.0 C) and P (16.0 C) although more fish were caught at station P. It appears that the plant's present discharge was elevating the temperature at Q, but spottails were not attracted to the warmer water in the beach zone as occurred in June. Possibly spottail distribution differences as indicated by seine catches were also influenced by schooling behavior of this species. Schooling by spottail shiners was documented by Nursall and Pinsent (1969) and Nursall (1973) in Beaver Lake, Alberta.

Day seine catches in July were lower than night catches, but moderate numbers of spottails were still caught (Fig. 35). While seine catches showed spottails were in the beach zone during the day and especially at night at all stations, the only other deeper station where spottails were caught was 1.5 m. A night gill net at station A (1.5 m - s.) caught 40 adult spottails (Figs. 39 and 40).

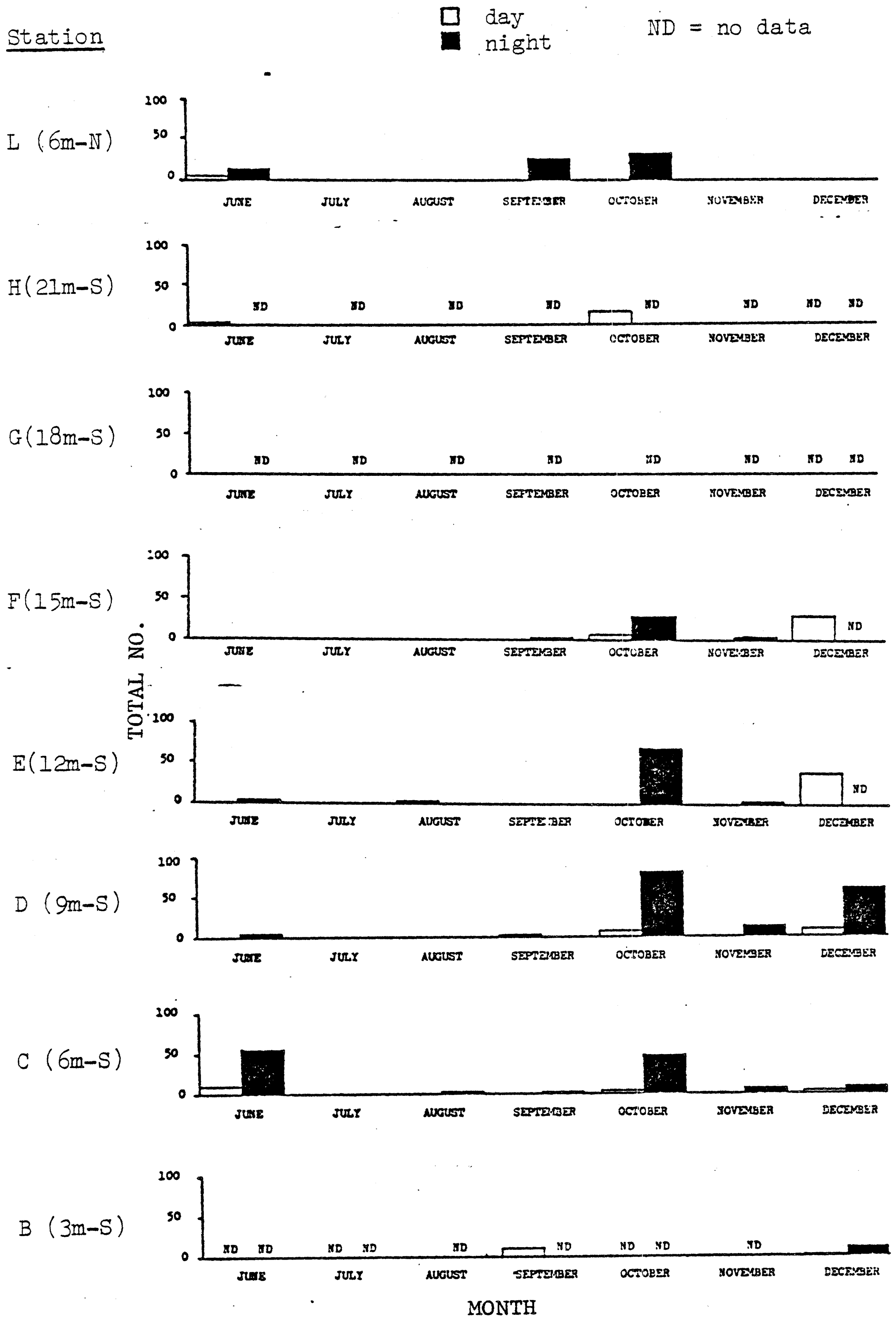


FIG. 37. Total number of spottail shiner caught in bottom trawls fished during day and night once per month June through December 1977 in eastern Lake Michigan in the vicinity of the J. H. Campbell Power Plant.

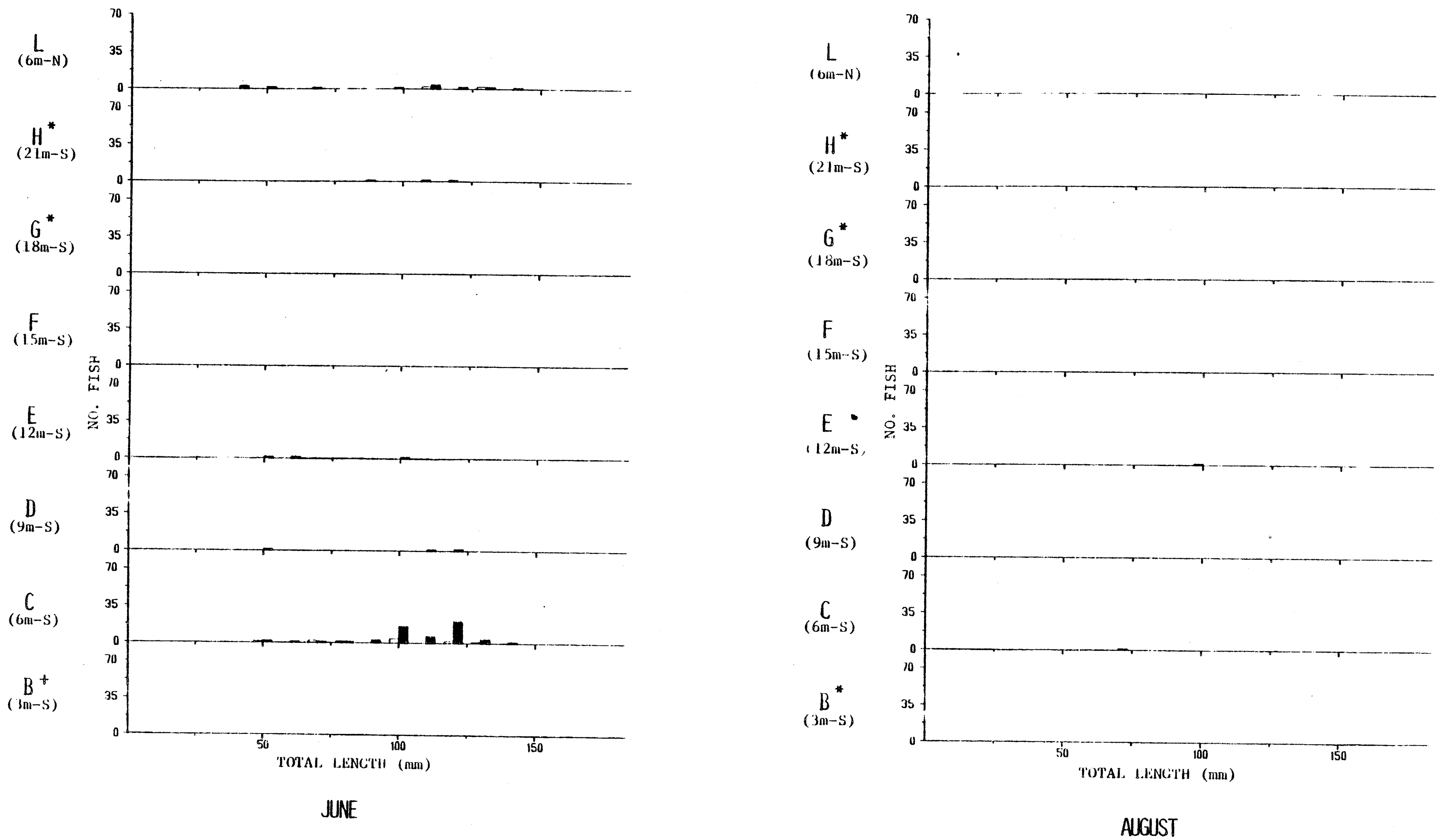


FIG. 38. Length-frequency histograms for spottail shiner caught in duplicate trawl hauls during June to December 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.
* = No night sampling performed.
+ = No sampling performed.

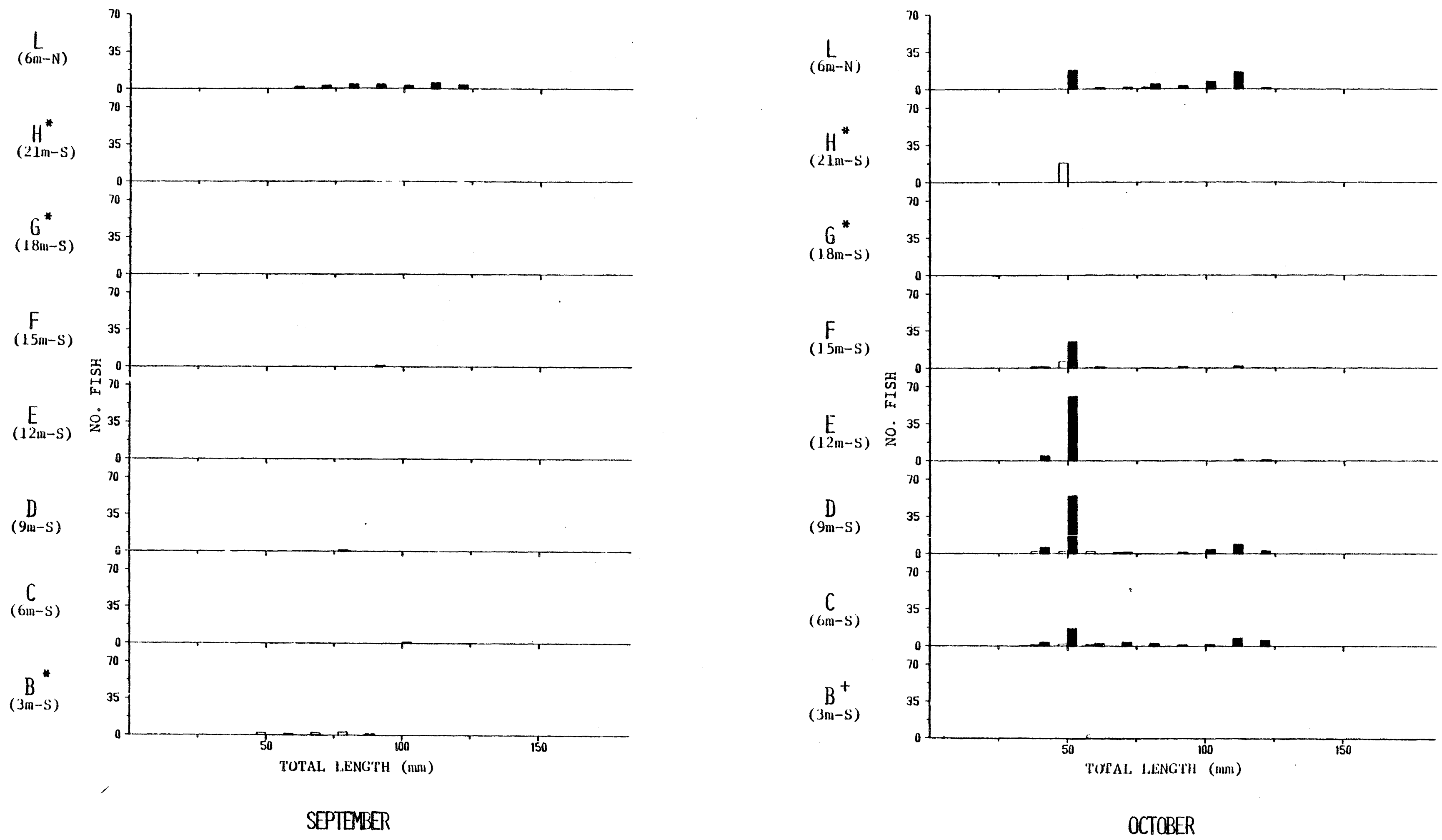
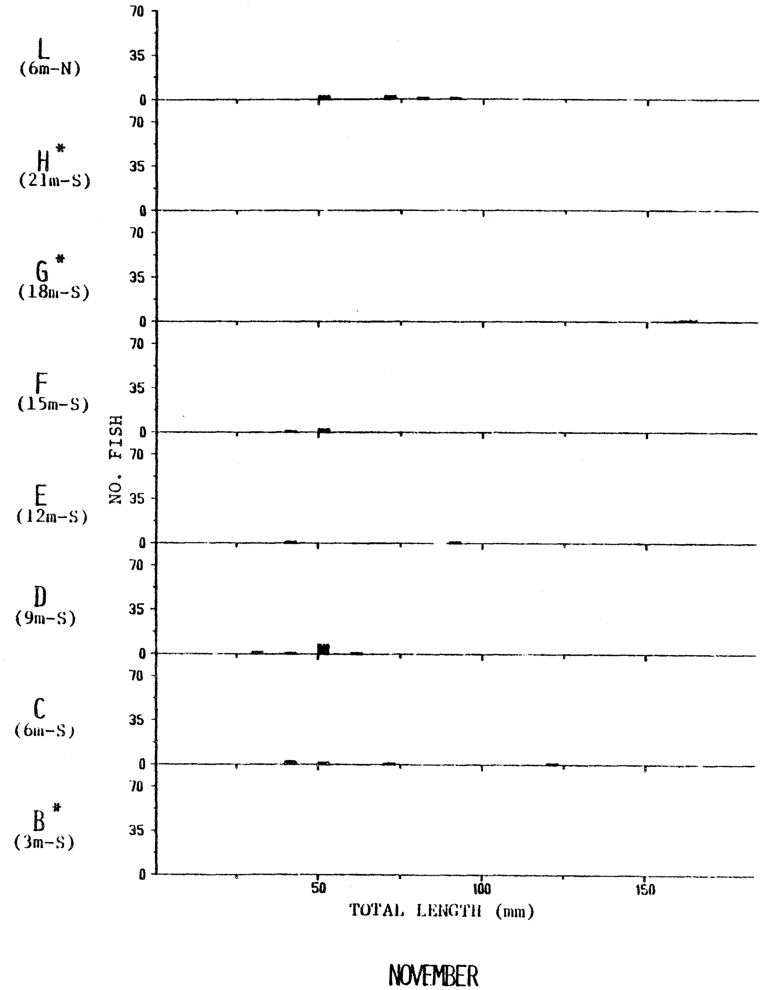


FIG. 38. (Continued)



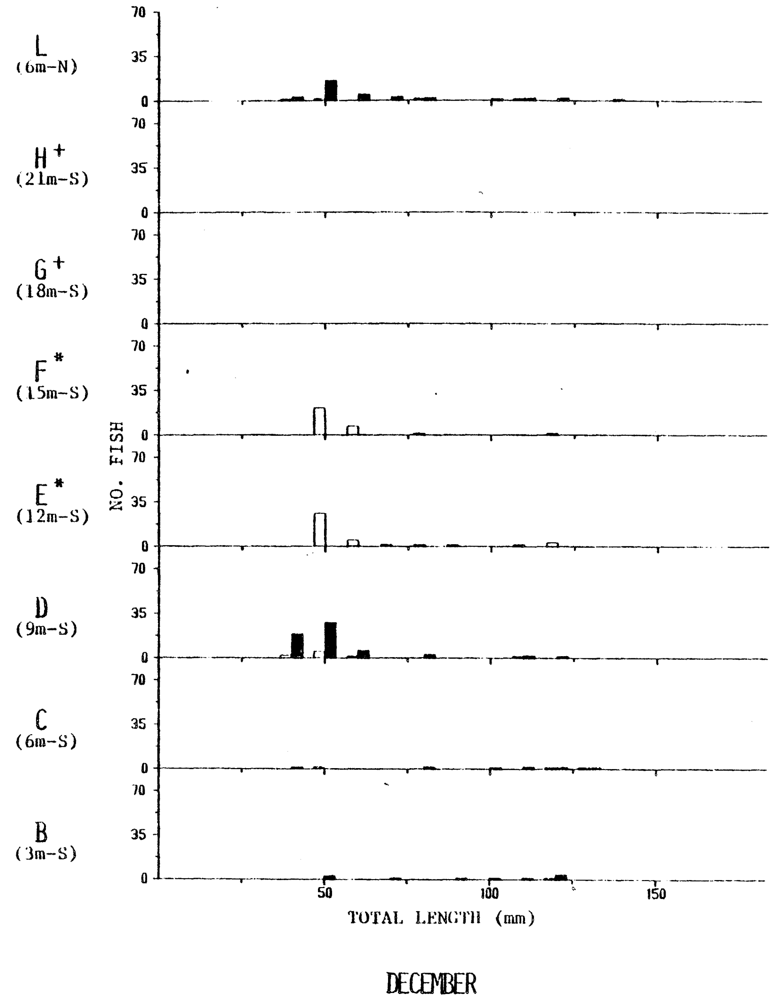


FIG. 38. (Continued)

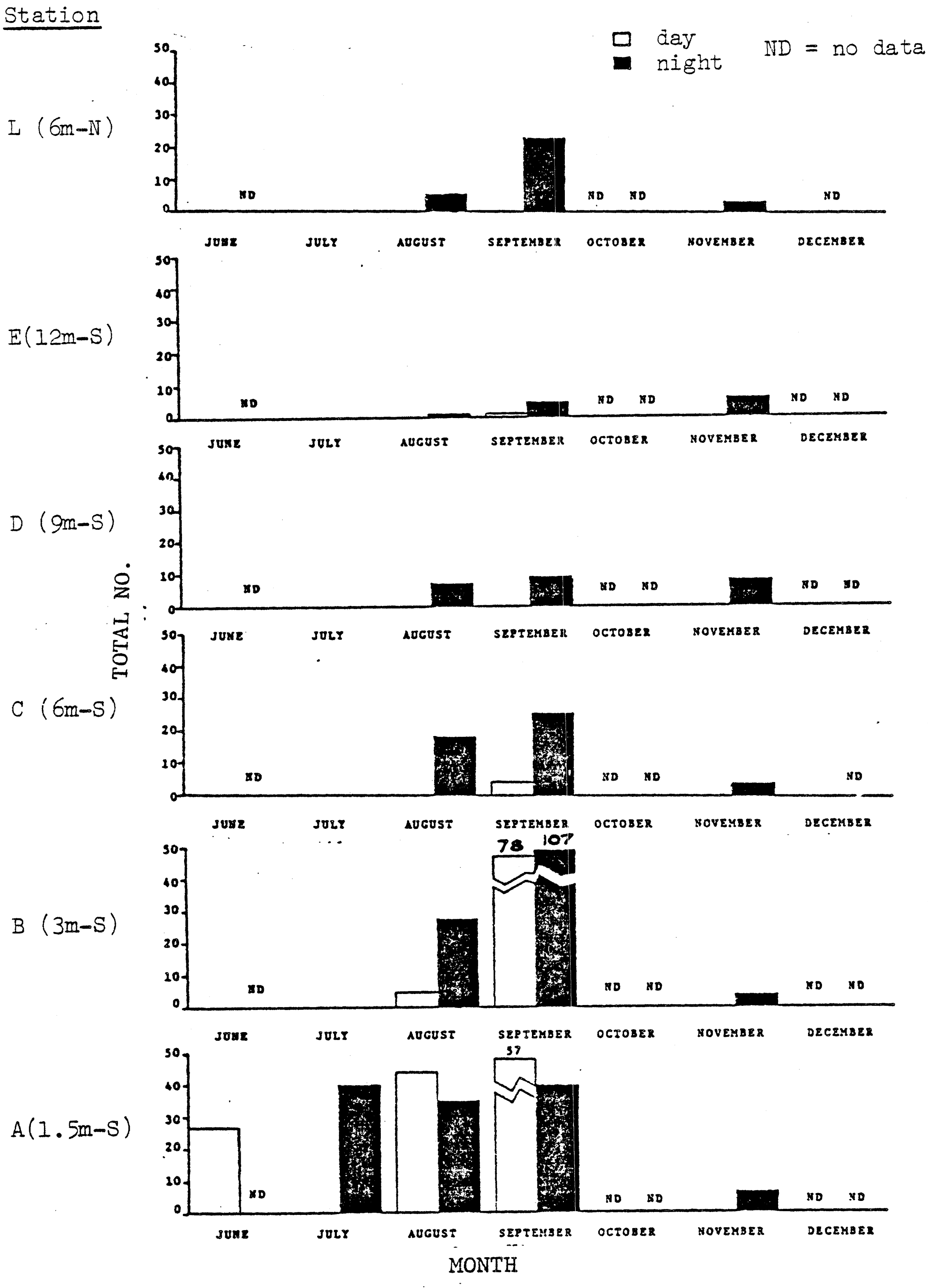
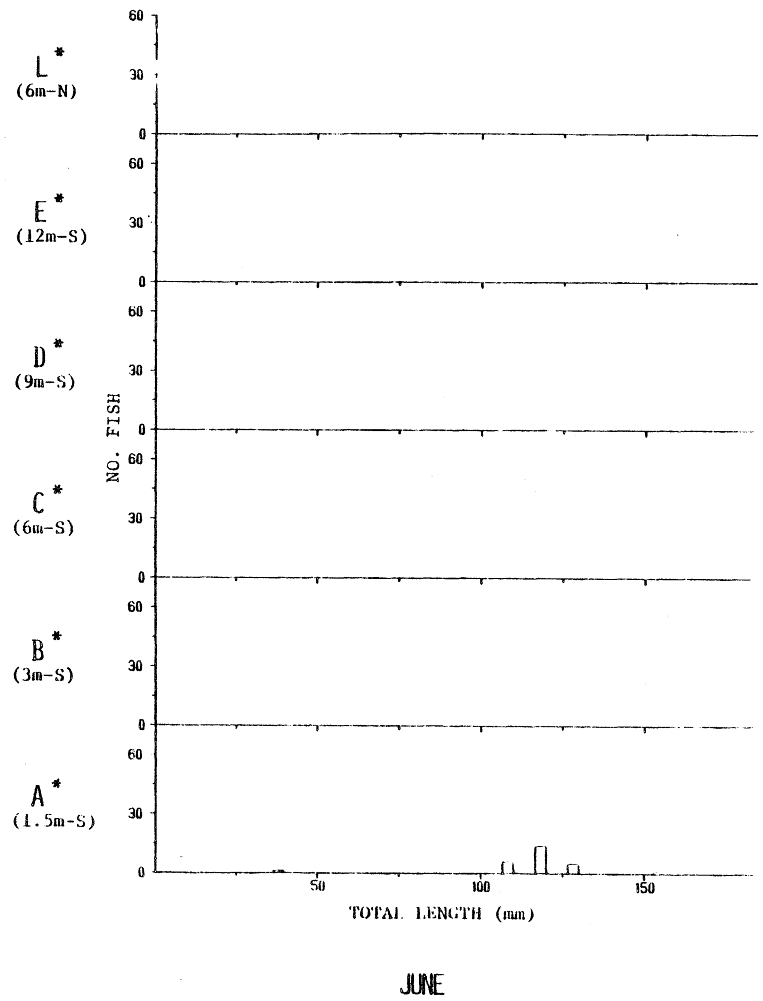


FIG. 39. Total number of spottail shiner caught in bottom gill nets fished during day and night once per month June through December 1977 in eastern Lake Michigan in the vicinity of the J. H. Campbell Power Plant.



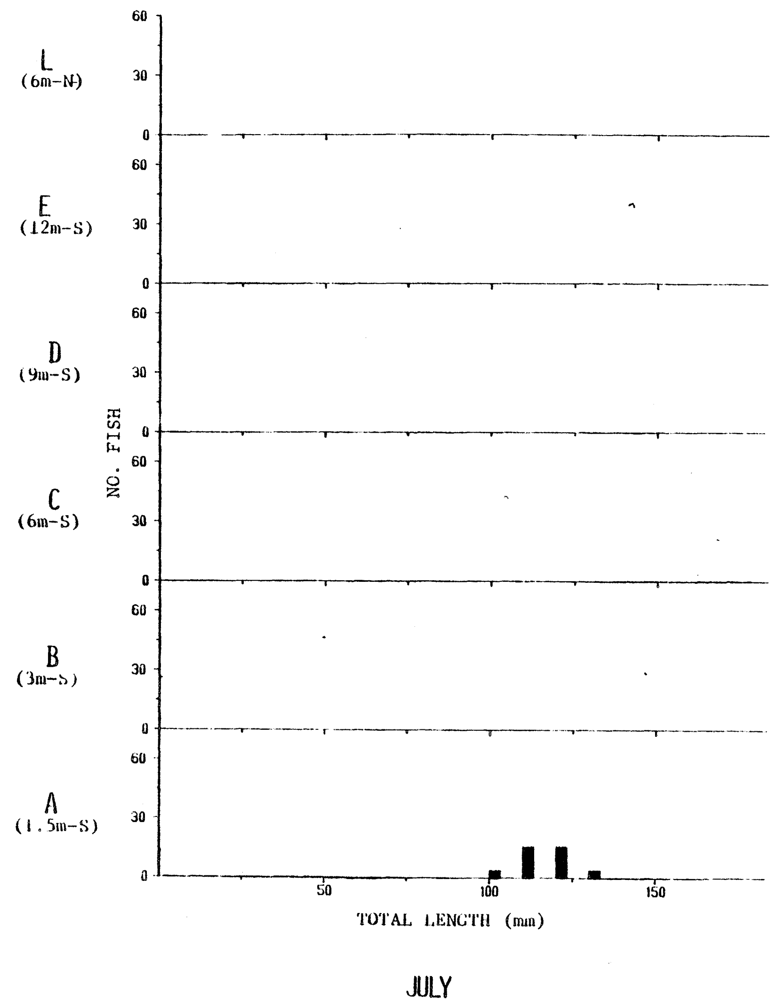


FIG. 40. Length-frequency histograms for spottail shiner caught in duplicate bottom gill nets during June to November 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.
* = No night sampling performed.

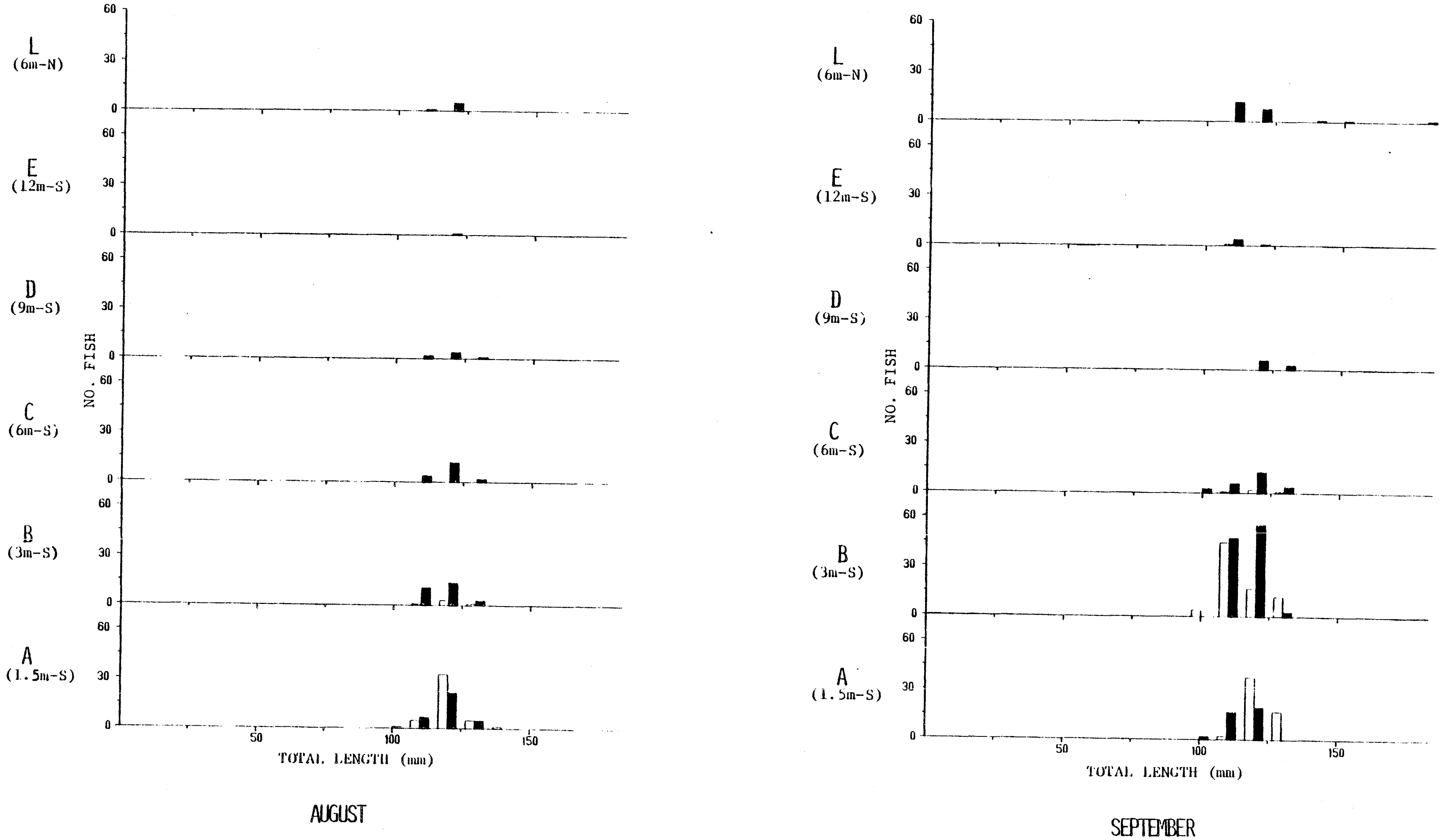


FIG. 40. (continued)

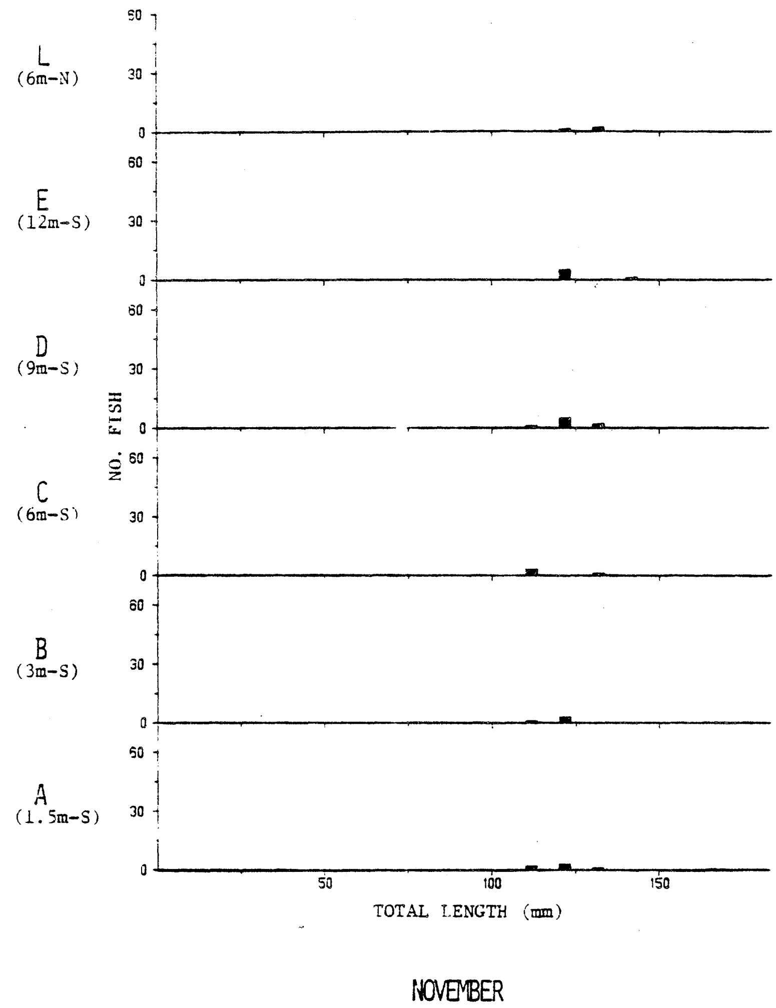


FIG. 40. (continued)

An interesting aspect of these data is that although spottails were occupying slightly deeper depths at night, seine catches were lower during the day. We suspect that daytime net avoidance was occurring. It seems very unlikely that fish moved along shore away from seine sampling stations.

All sizes of juvenile (yearling) and adult spottails were caught by day and night seine hauls in Lake Michigan during this study (Fig. 36). Size distribution was bimodal with a peak at 60-70 mm and one at 100-110 mm. Based on age data given by Wells and House (1974) for Lake Michigan spottails, those captured by seine during the Campbell study would most likely be age-group 1 (60-70 mm) and age-groups 2 and 3 (100-110 mm). One small (22 mm) spottail was seined during the day in July at beach

TABLE 26 . Monthly gonad conditions of spottail shiners caught in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development	2	36	47	60	33	7	9
	Mod. development	23	27	12	20	13	16	11
	Well developed	8	2		1		10	
	Ripe-running							
	Spent	1	1					
Females	Slight development		35	60	56	7	3	8
	Mod. development	10	15	5	26	22	4	16
	Well developed	88	4				4	
	Ripe-running				1			
	Spent	4	14	3	10			
	Absorbing				3			
Immature		27	92	97	223	69	43	98
Unable to distinguish		17	37	8	17		1	5

station Q. This fish was obviously a YOY. Many small fish (20-40 mm) were seined in Pigeon Lake in July (Fig. 41) and we believe these fish were also YOY. This July occurrence of YOY predominantly in Pigeon Lake supports our hypothesis that some spottails spawned in Pigeon Lake in May approximately 1 or 2 months before most spawning occurred in Lake Michigan. Jude et al. (1979) also found some spottail larvae around the Cook Plant in May.

In contrast to Lake Michigan seine catches, day seine catches of spottails in Pigeon Lake were larger than night catches (Fig. 42). Schooling behavior was responsible for some of these catch differences. Approximately 89% of the day seined spottails came from one seine haul at beach station S (influenced by Lake Michigan). Station S was a preferred habitat for YOY spottails in Pigeon Lake. No spottails were seined in July at station T (influenced by Pigeon River) and only a few were seined at station V (undisturbed Pigeon Lake). Possibly fish were avoiding areas of Pigeon Lake that had high densities of aquatic vascular plants.

August -- Total number of spottails caught in Lake Michigan increased in August (1444 fish) compared to July (1207 fish). As in

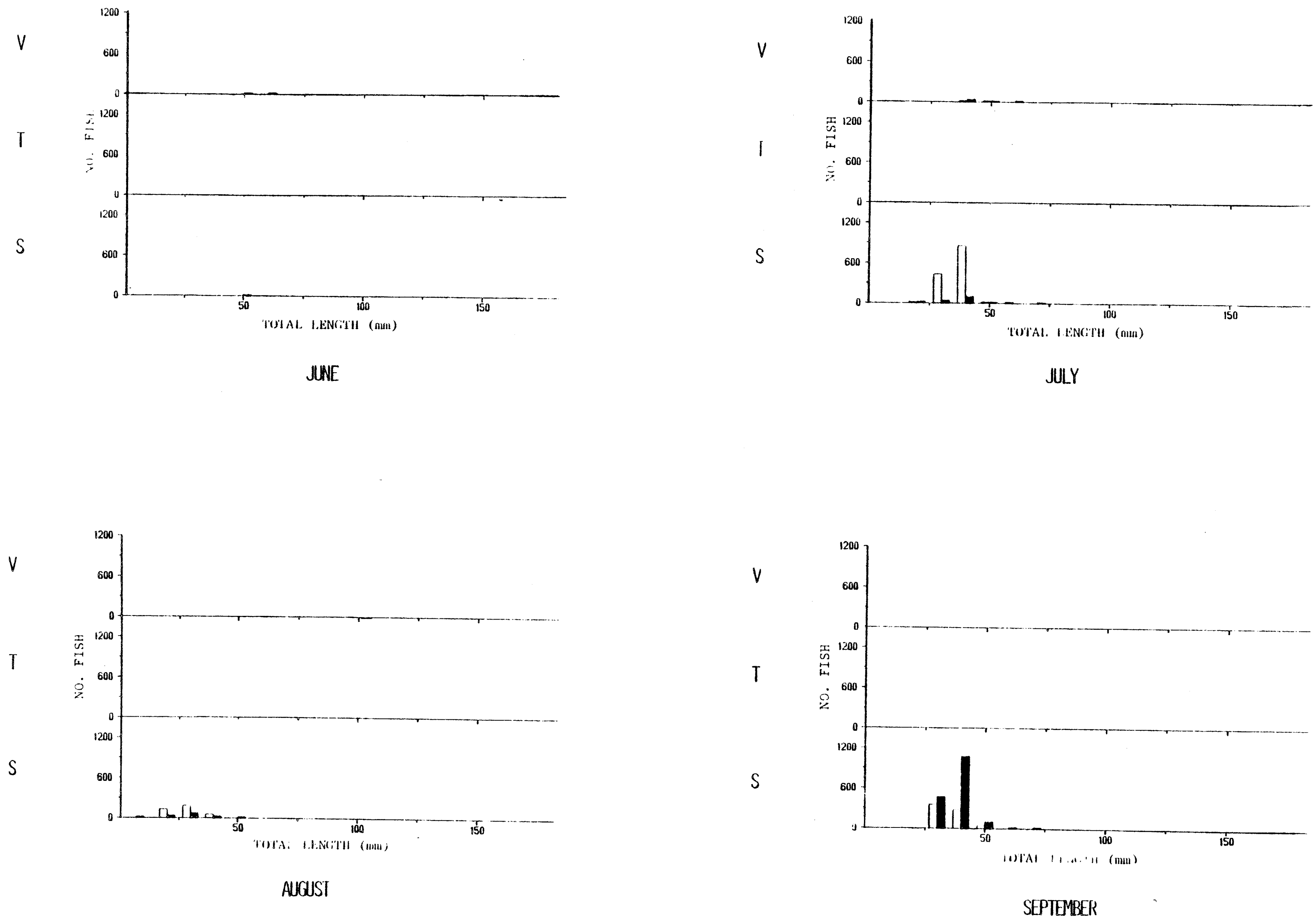


FIG. 41. Length-frequency histograms for spottail shiner caught in duplicate seine hauls during June to November 1977 in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan. □ = day ■ = night.

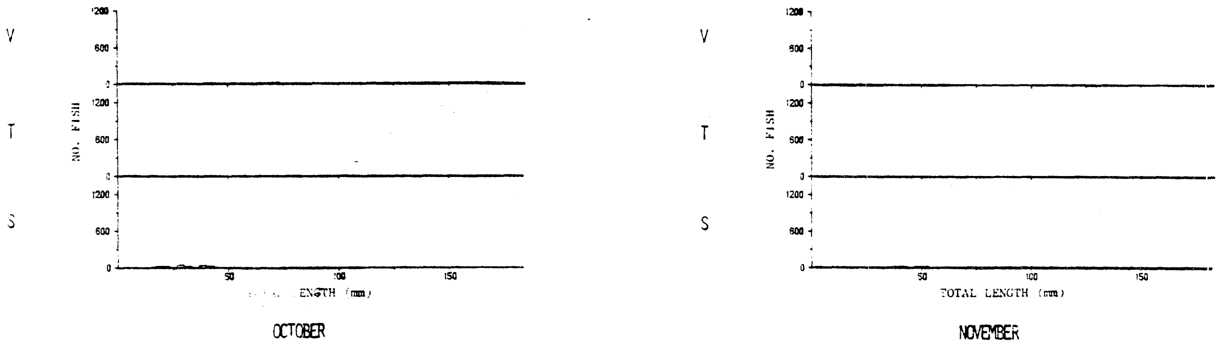


FIG. 41. (Continued)

June and July the majority (90%) of fish caught in August were seined. In contrast to June and July, more fish were seined during the day than at night (Fig. 35). Day seines at station R (n. discharge) contained the most fish. These day-night catch differences can be attributed to size-class variation among the fish. At Lake Michigan beach station P more adult and yearlings were caught than at station Q and R where YOY predominated (Fig. 36). Adults and yearlings were caught at night while YOY were caught during the day. Seine catches in Pigeon Lake only occurred at beach station S (influenced by Lake Michigan) where YOY were also more abundant during the day than at night (Fig. 41).

Bottom gill net catches of adults (our gill nets do not effectively sample YOY and small yearling spottails) in Lake Michigan showed most were at 1.5 m with a few out at 3 m during the day (Fig. 40). At night, gill nets showed a progressive decline in abundance of adult spottails from 1.5 m to 12 m (Fig. 40). While night gill nets were collecting adult spottails, only two fish were caught by night trawling in August (Fig. 37). It is possible that some spottails can evade the trawl, but we suspect the efficiency of gill nets in capturing spottails was a result of the long fishing time (approximately 12 hr compared to 10 min for trawl hauls). Spottails probably move from shore to deeper water at sunset and back during or near sunrise hours, near the time when gill nets would still be set.

September -- The September catch of spottail shiners was the largest monthly catch in both Lake Michigan (4018 fish) and Pigeon Lake (2333 fish) during 1977. Day seines made up 90% of the Lake Michigan total catch with 80% of this day catch occurring at beach station Q (Fig. 35). Warm water from the plant's discharge apparently attracted spottails to station Q (s. discharge); a similar attraction of spottails to station R (n. discharge) occurred in June. Water temperatures recorded during September day seining were 15.6 C at Q, 12.2 C at R (n. discharge) and 11.1 C at P (s. reference).

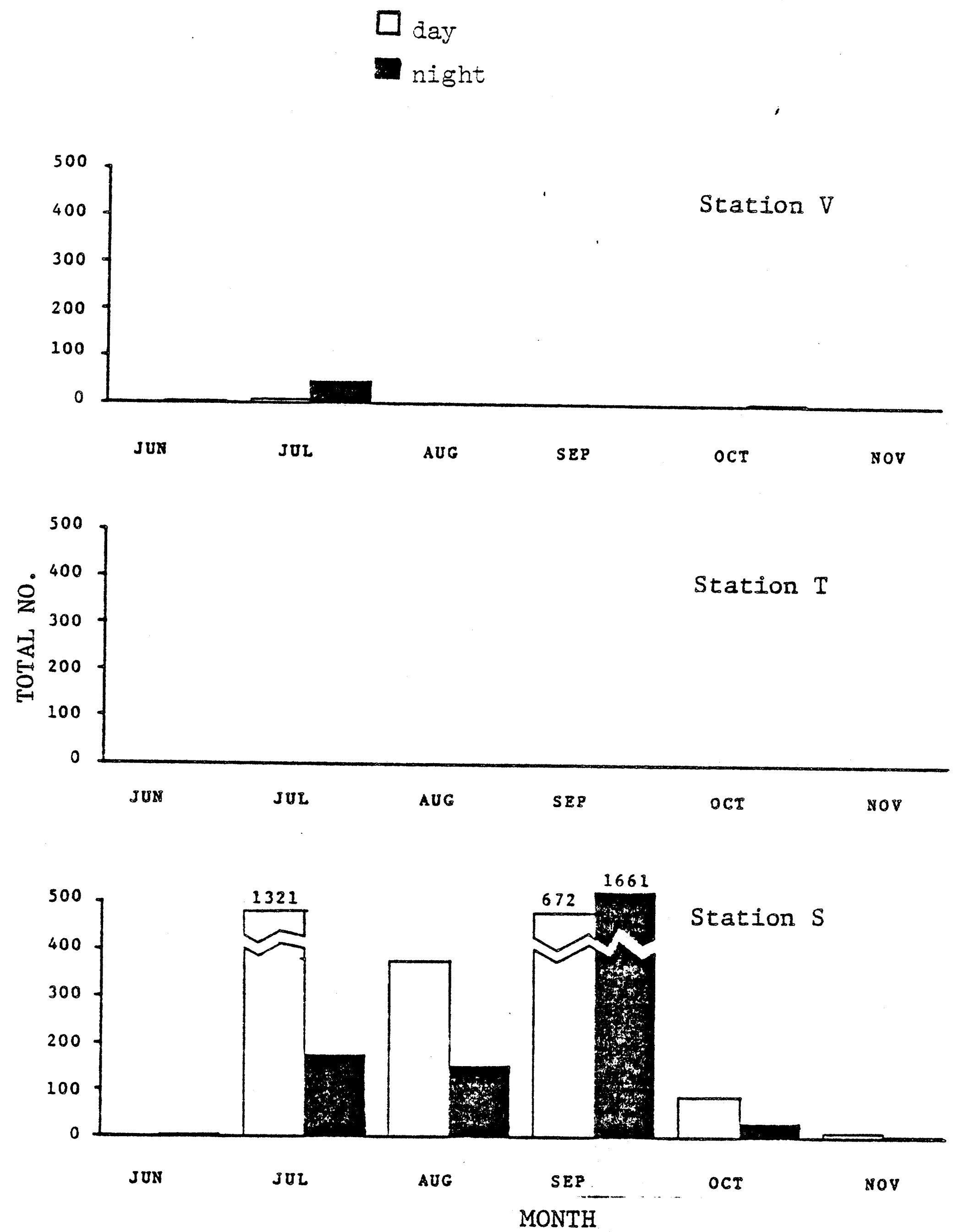


FIG. 42. Total number of spottail shiner caught in duplicate seine hauls in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, June - November 1977.

The majority of spottails caught by September day seining in Lake Michigan were smaller fish from 30-90 mm (Fig. 36). Most of these fish were YOY, but some may have been yearlings. Suspected early spawning in Pigeon Lake confounded interpretation of ages from length sizes. YOY from southeastern Lake Michigan were 30-60 mm in September 1974, while yearlings were 70-100 mm (Jude et al. 1979). These data would indicate that in the present study, spottails from 30-60 mm were YOY and those from 70-90 mm were yearlings, but spottails from early hatchings in Pigeon Lake might be in the 70-90 mm range by September.

Bottom gill net data showed adult spottails at 1.5 to 6 m during the day, with largest catches at 1.5 and 3 m (Figs. 39 and 40). At night, spottails extended their depth range out to 12 m and probably deeper [a few were trawled at 15 m (Fig. 37)]. Day and night trawl hauls caught few adult spottails, but some yearlings were caught at 3 m (Fig. 38).

During September only YOY were seined in large numbers in Pigeon Lake at beach station S (influenced by Lake Michigan) (Fig. 41). In contrast to July and August, more YOY were seined at night in September (Fig. 41). We can only conjecture that schooling behavior caused this large night catch, but both night seine hauls contained large numbers of YOY spottails.

October -- Number of spottails caught in Lake Michigan during October (366 fish) declined drastically compared with the September catch (4018 fish). Part of this decline was the result of less fishing effort in October (gill nets were not set because of storms), but most was due to the annual migration of spottails to deeper water. Wells (1968) recorded spottails at 6-31 m in southeastern Lake Michigan during October, with highest numbers at 22 and 27 m. Jude et al. (1979) also indicated that spottails migrated to deeper water in the fall in southeastern Lake Michigan.

Few spottails (52 fish) were caught by seining in the Lake Michigan beach zone; most fish were YOY and yearlings (Fig. 36 and Appendix 5). Seining in Pigeon Lake also showed most spottails had left there by October. Most of the population was in the deeper water of Lake Michigan.

Trawl samples in October showed no adult spottails were in the sampling depths during the day (Fig. 38). From Wells (1968) trawling study we surmised that adults were in deeper water outside our study area. At night some smaller adults moved into the trawling depths with most being found at 9 and 6 m (no trawling occurred at 3 m). Yearlings also followed this day-night pattern. Most YOY were apparently in deep water during the day in October; highest day catch occurred at 21 m, but some were caught at 6, 9 and 15 m (Fig. 38). At night some YOY moved

into the study depth zones. Night trawl catches occurred from 6-15 m (no trawling occurred at 21, 18 and 3 m). We suspected that YOY were also at 21, 18 and 3 m during the night.

November, December -- The November catch of spottails (88 fish) was the lowest of any sampling month. As was found in October, the bulk of the population was in water deeper than 21 m. Some fish did enter the study depths at night (Figs. 37 and 39). Also a few YOY spottails were still found in Pigeon Lake (Fig. 41). This pattern continued in December although more fish were caught (198 fish). In Lake Michigan, fish (all sizes but mostly YOY) were caught by day and night trawling in December (Fig. 38). Although the bulk of the population was in deeper water, some individuals entered the inshore waters of eastern Lake Michigan during late fall and early winter. Jude et al. (1979) also found the same spatial distribution of spottails in southeastern Lake Michigan. Impingement data from the Campbell Plant during 1974-1975 (Consumers Power Company 1975) showed some spottails were probably present during fall and winter months in Pigeon Lake.

Temperature-Catch Relationships -- Smaller spottails were caught at higher temperatures than larger fish in both Lake Michigan and Pigeon Lake (Fig. 43). Apparently age influences temperature selection by spottails. Jude et al. (1979) also found a similar size-temperature relationship for spottail shiners caught in southeastern Lake Michigan. Standard deviations around the mean did indicate large variation among sizes (Fig. 43).

Approximately 69% of our spottail catch in Lake Michigan occurred between 11-17 C. Jude et al. (1979) found the majority (74%) of their spottail catch in southeastern Lake Michigan at temperatures from 18-27 C. Wells (1968) trawled most spottails at 13-22 C in southeastern Lake Michigan. These differences in relationships of temperature with catches were probably related more to water temperatures available to the fish rather than to strictly temperature preference of the fish. Spottails preferred shallow depths and apparently did not move from the shallows extensively following movements of warmer water. We suspect that spottails preferred warmer temperatures in Lake Michigan.

Other Considerations -- Spottails were not heavily preyed upon by piscivorous fish in the study areas as no spottails were found in stomachs of predatory fish examined. Jude et al. (1979) also found that spottails were not preyed upon to any great extent in southeastern Lake Michigan.

Summary -- Spottail shiners were the third most abundant fish collected from June to December 1977 in the vicinity of the J. H. Campbell Plant. During summer and especially early fall they were seined in large numbers from Lake Michigan and Pigeon Lake, but all

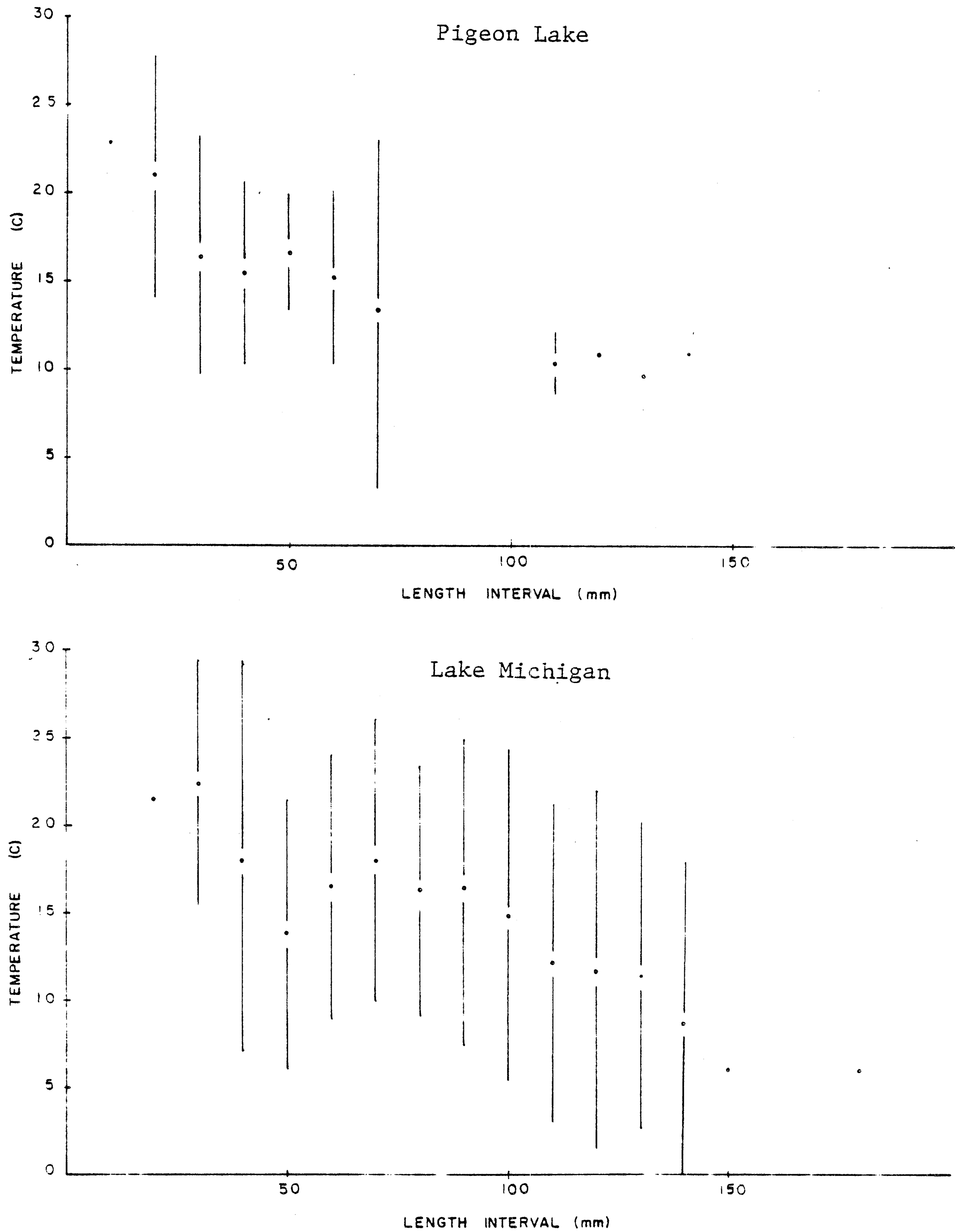


FIG. 43. Weighted-mean temperatures for 10 mm length intervals of spottail shiners caught by all gear types from Pigeon Lake and Lake Michigan in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1977. Vertical lines represent $\pm$ 2 standard deviations.

catches declined in late fall and early winter as fish migrated to deeper water. All age groups were caught in Lake Michigan (84% of the catch by seining, 9% by trawling, and 7% by gillnetting), while predominately YOY were caught in Pigeon Lake (99% by seining).

Gonad data and catch data of larval and YOY spottails indicated that spottails spawned in Lake Michigan during June and July from 9 m to shore; spawning was probably heaviest in the nearshore area. Early occurrence of larvae (early June) and YOY (July) in Pigeon Lake suggested that spottails spawned there in May. The nearshore area of Lake Michigan and the west side of Pigeon Lake served as nursery areas for spottail shiners.

From June through September adults and yearlings were concentrated between 1.5 and 3 m during the day in Lake Michigan. At night fish were dispersed from shore to 12 to 15 m. Only during July, when spawning was probably at a peak, did spottails concentrate day and night in the beach zone. September day catches showed spottails were segregated by size and depth; adults were in the beach zone to 3 m, yearlings from the beach zone to 1.5 m and YOY in the beach zone. In October, November and December the bulk of the spottail population was in water deeper than 21 m, but some individuals entered study depths at night.

Smaller spottails were caught at higher temperatures than larger fish; 69% of the fish collected in Lake Michigan occurred at water temperatures of 11-17 C. Only one spottail was caught by surface gillnets, which demonstrated the fishes' benthic habits. Spottails in the study area were not heavily preyed upon by picivorous fish.

Yellow Perch --

Introduction -- The yellow perch is a highly adaptable percid fish which occurs throughout most of northern North America. Habitat for this species includes small or large clear lakes with moderate vegetation, as well as quiet rivers (Scott and Crossman 1973). In Lake Michigan, the yellow perch is abundant in protected bays, notably Green Bay, and moderately abundant in shoreline areas with depth less than 40 m (Wells and Mclain 1973).

Historically, the abundance of yellow perch in Lake Michigan fluctuated greatly. Declines in population have been related to the spread of non-native alewife (Wells 1970) and, although the exact mechanisms involved are not understood, Wells (1977) has suggested several possible causes. Generally it is believed that the alewife inhibited the reproduction of yellow perch to some degree. Development of the strong 1969 yellow perch year class following the massive

1967-1968 die off of alewives further suggests the interdependency between yellow perch and alewife populations.

The commercial and recreational importance of yellow perch has resulted in considerable study of its life history in other parts of its range (Scott and Crossman 1973) and will not be considered here. Comprehensive studies of the life history of this species in Lake Michigan are notably lacking. Studies by Wells (1968), Brazo et al. (1975) and Jude et al. (1975) elucidated the seasonal depth distribution of yellow perch in east-central and southeastern Lake Michigan, but it is evident that more study of this important species is needed to better understand its role in the ecology of the lake.

Yellow perch are common to abundant near the Campbell Plant, comprising 11.9% (2459 fish) of the catch by number in Pigeon Lake, and 1.6% (1254 fish) of the Lake Michigan catch (Tables 13 and 14). Bottom gill nets made up 6% of the catch in Pigeon Lake (Table 14 and 19) and 57% of the catch in Lake Michigan (Table 13 and 15). Seine hauls comprised 94% of the Pigeon Lake catch (Table 14 and 20) and 26% of the Lake Michigan catch (Table 13 and 18). Trawling, which was only performed in Lake Michigan, accounted for 16% of that catch (Table 13 and 17).

Seasonal distribution --

June -- Sampling near the J. H. Campbell Plant began in early June. At this time, day trawl samples as well as day and night bottom gill net samples from Lake Michigan indicated yellow perch were generally at depths of 12-21 m, with some taken at shallower depths (Figs. 44 and 45). No yellow perch were taken by seine in early June indicating their absence from the beach zone. Wells (1968) observed that adult yellow perch began to move into shallow water (6, 9 and 13 m) in late May during 1964 in southeastern Lake Michigan. Brazo et al. (1975) found that most yellow perch were in deeper water (24 m) during early April 1972 in east-central Lake Michigan (near Ludington) but migration of male perch into shallow water 6-12 m, had occurred in late May when water temperatures had reached 6-7 C. It is evident from our data that this inshore movement had already occurred in the area of the Campbell Plant prior to initial sampling in June. Yellow perch present at this time were primarily longer than 150 mm, 2 yrs and older, (Scott and Crossman 1973) but some smaller perch (<100 mm - probably yearlings) were also observed at 12 and 15 m (Fig. 46). Water temperatures in the area of the Campbell Plant during early June sampling ranged from 7.4-11.7 C (Appendices 1-3). Movement of yellow perch into shallow water in spring is usually associated with spawning. We observed ripe and ripe-running perch in our Lake Michigan catches in June (Table 27). Some success of spawning in Lake Michigan near the Campbell Plant was apparent from the presence of larval yellow perch in late June at south

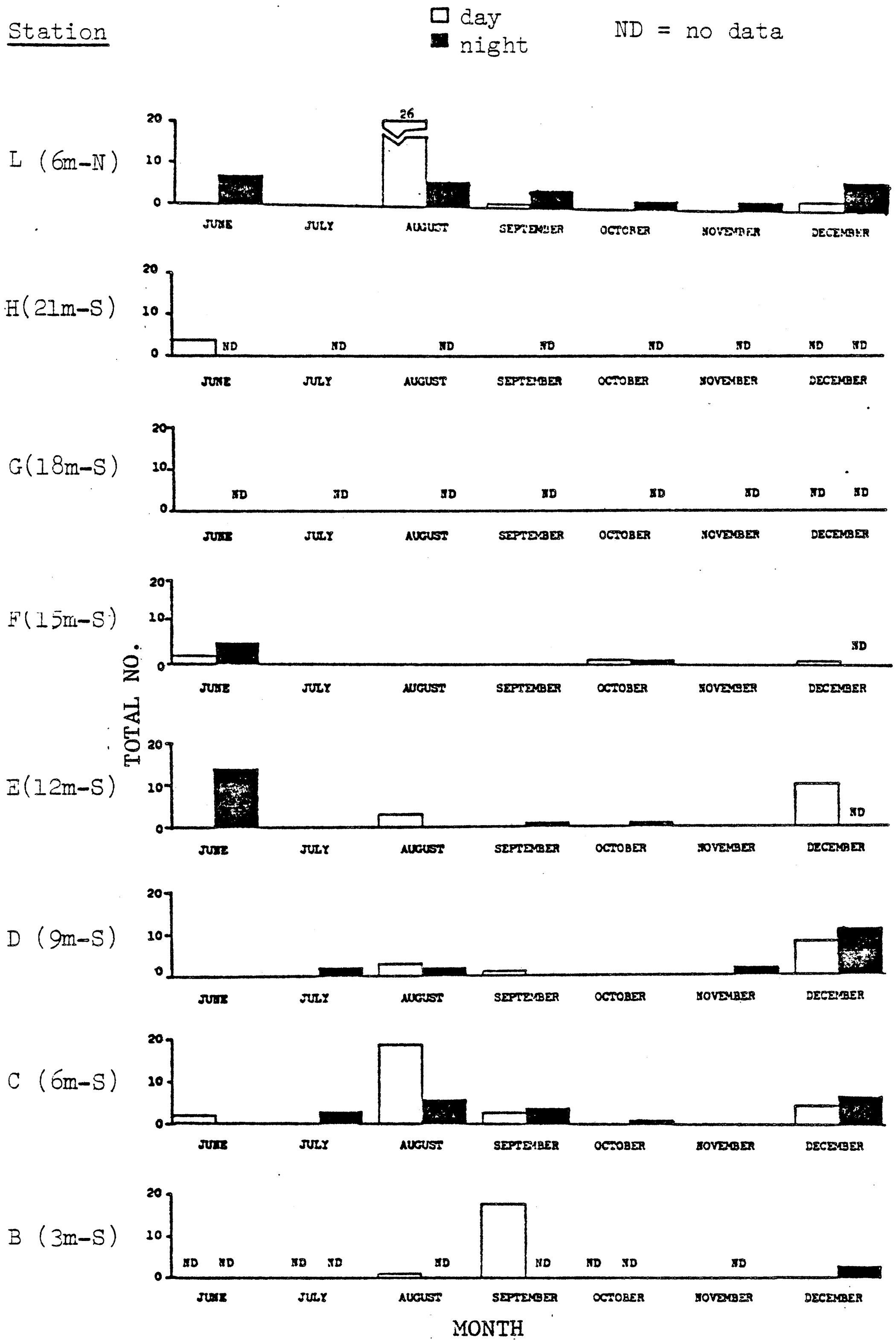


FIG. 44. Total number of yellow perch caught in bottom trawls fished during day and night once per month June through December 1977 in eastern Lake Michigan in the vicinity of the J. H. Campbell Power Plant.

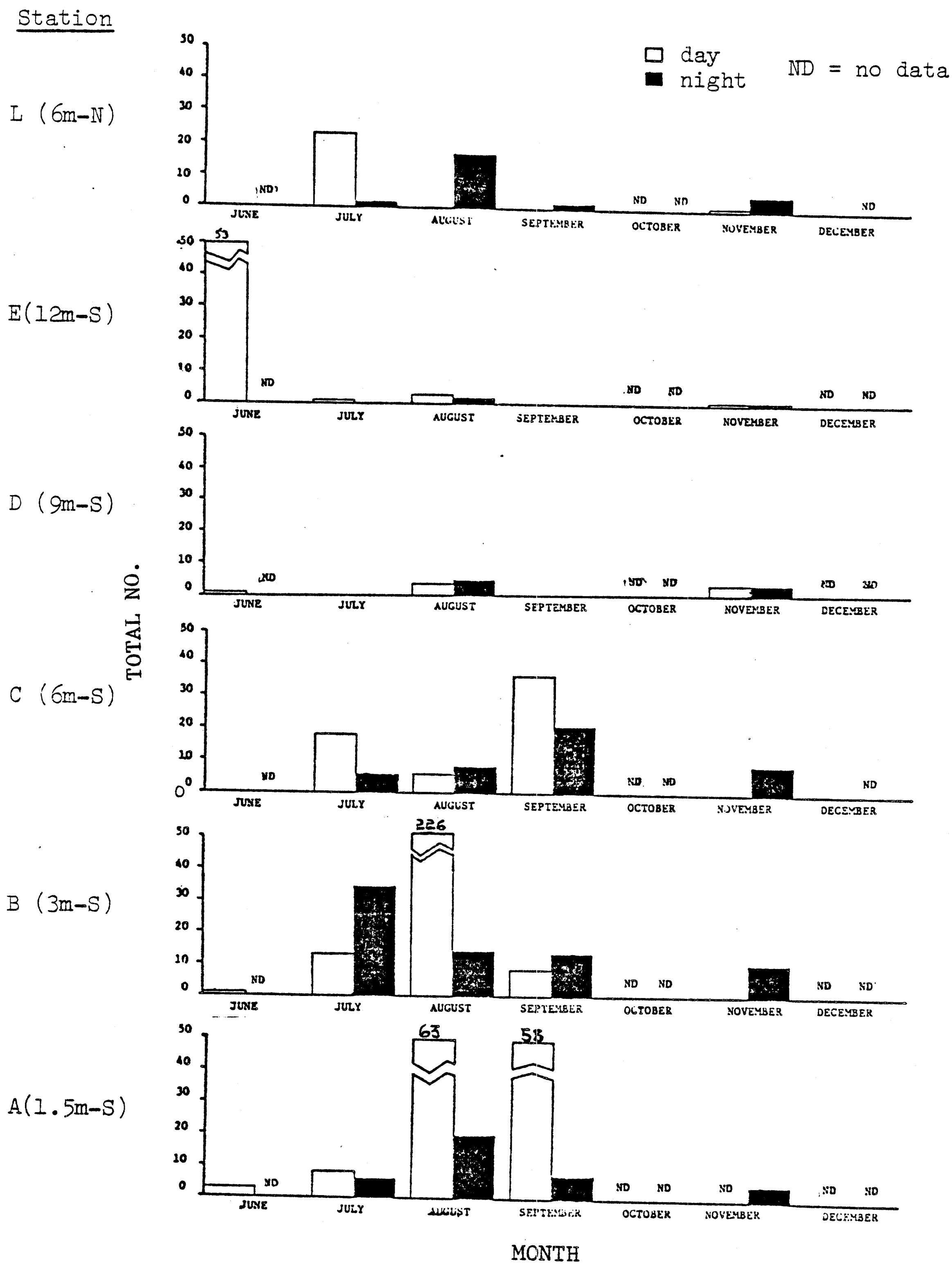


FIG. 45. Total number of yellow perch caught in bottom gill nets fished during day and night once per month June through December 1977 in eastern Lake Michigan in the vicinity of the J. H. Campbell Power Plant.

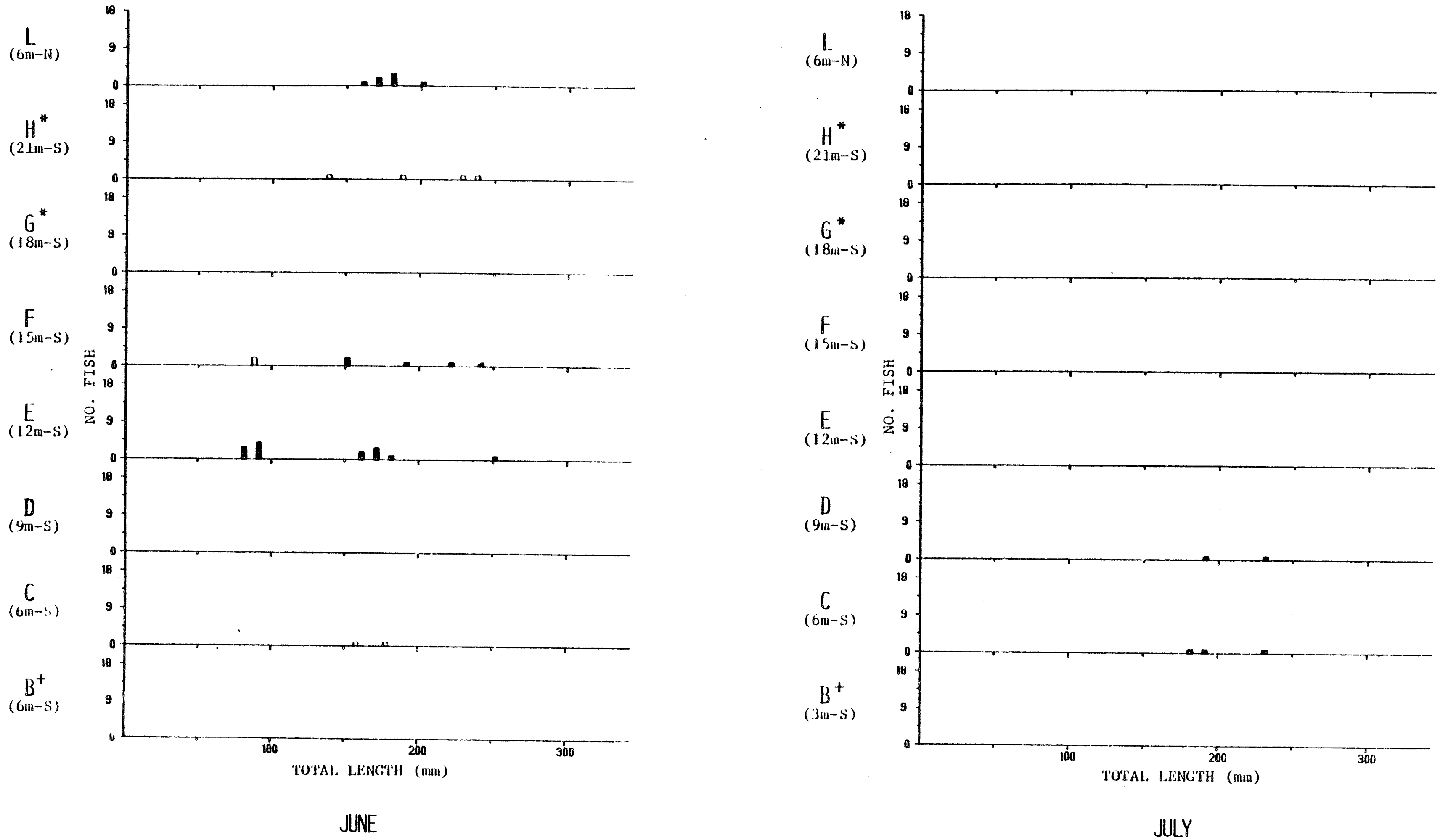


FIG. 46. Length-frequency histograms for yellow perch caught in duplicate trawl hauls during June to December 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.

□ = day ■ = night.

* = No night sampling performed.

+ = No sampling performed.

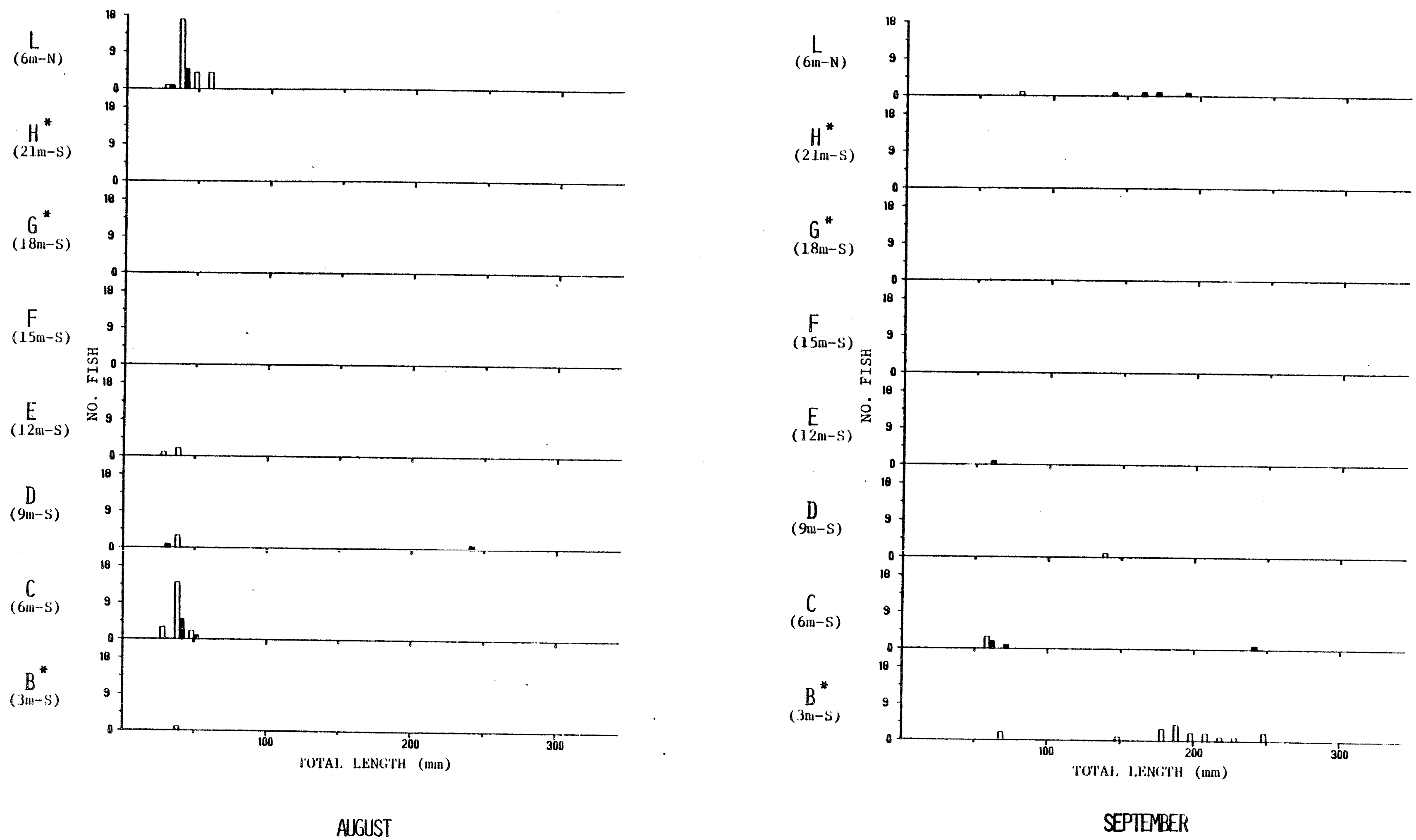
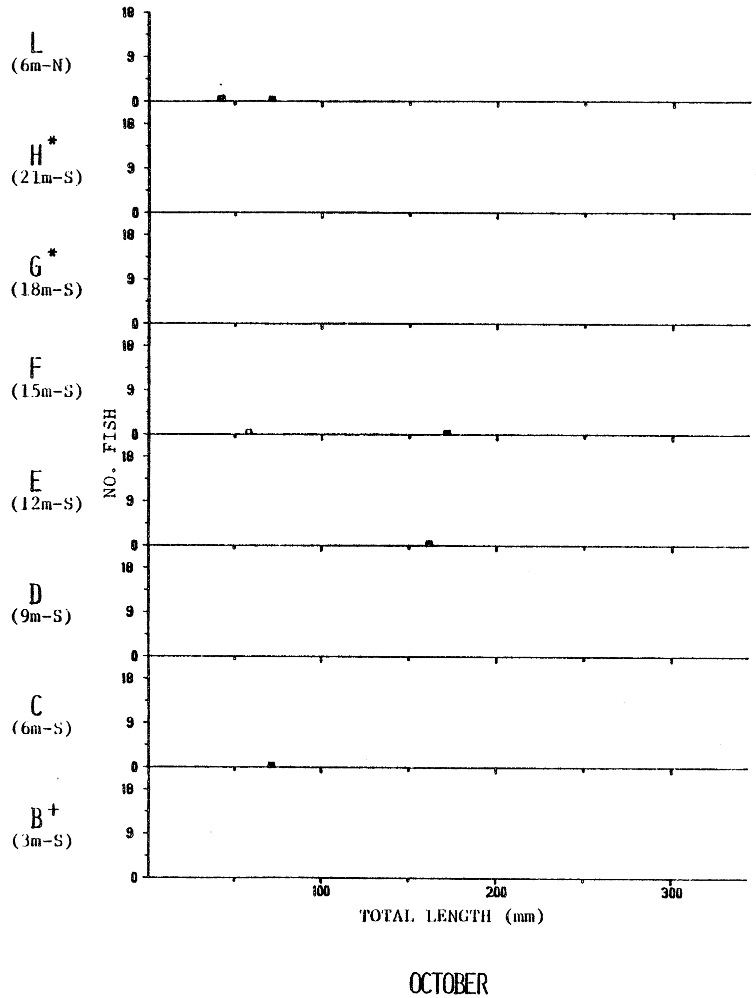


FIG. 46. (Continued)



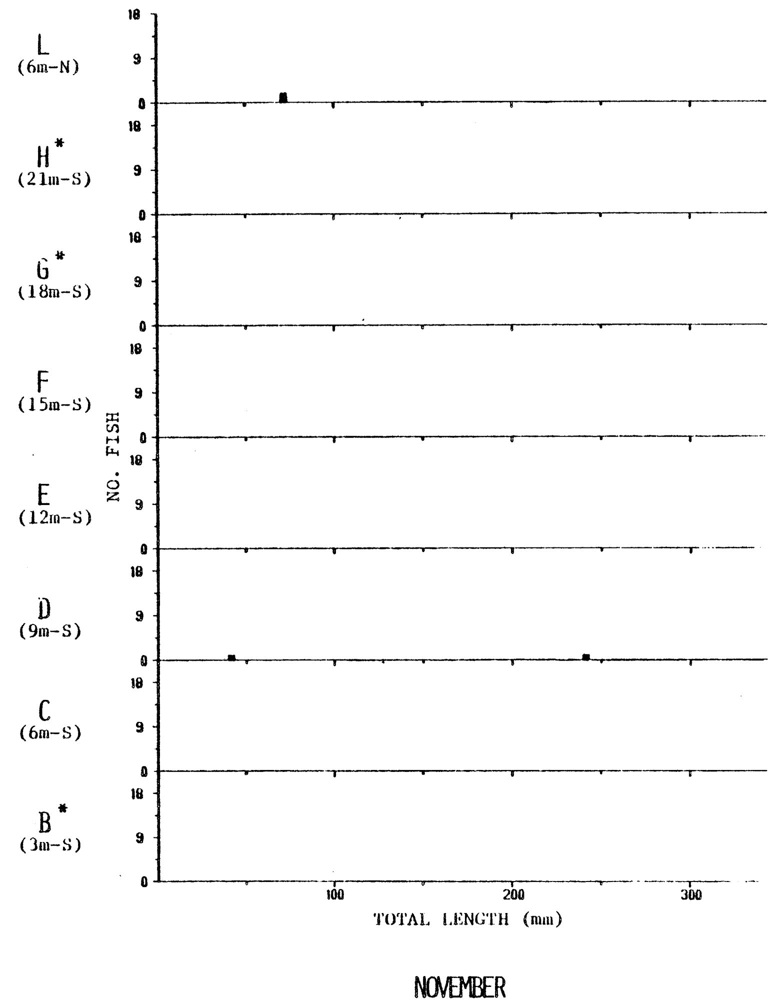


FIG. 46. (Continued)

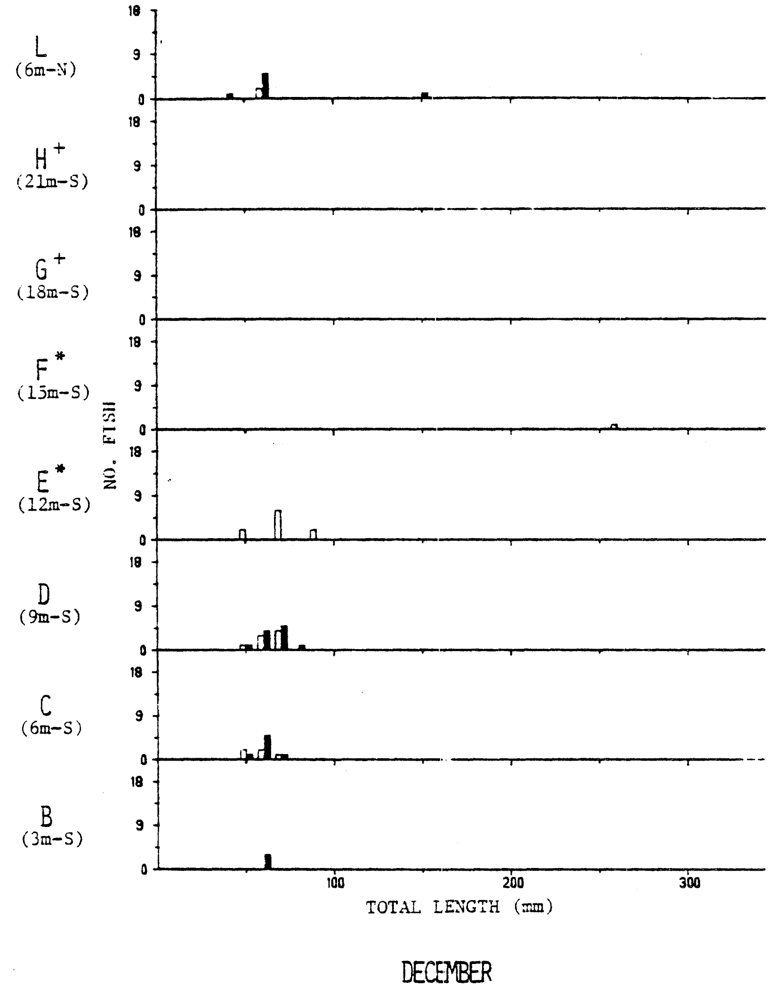


FIG. 46. (Continued)

transect stations (see FISH LARVAE AND ENTRAINMENT).

In Pigeon Lake during June, both large and small yellow perch were most abundant at beach station T (influenced by Pigeon River). High catches of YOY at station T during June probably reflects the suitability of this densely vegetated habitat for spawning and rearing, and suggested an April spawning period in Pigeon Lake in 1977. Gonad data of yellow perch from Pigeon Lake in June (Table 28) indicated that some spent individuals were present. The majority of adults had slightly developed gonads, indicating that regeneration of gonadal tissue following 1977 spawning was beginning. April spawning in 1978 was indicated by observations of a few masses of yellow perch eggs near beach station T, as well as observations of perch larvae in entrainment samples in April and May 1978. Larger perch (>125 mm) at Pigeon Lake openwater stations during early June were more abundant in bottom gill net samples at openwater station M (influenced by Lake Michigan) than at station Y (influenced by Pigeon River). Greater abundance of yellow perch at station M may be due to the reduced amount of vegetation and

TABLE 27. Monthly gonad conditions of yellow perch caught in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development	4	48	91	16	2	1	
	Mod. development	13	6	6	36	1	7	
	Well developed	11			33		25	1
	Ripe-running	9						
	Spent	14	5	20	12			
Females	Slight development	7	50	68	27			
	Mod. development		1		27		1	
	Well developed	1			7		5	
	Ripe-running	3						
	Spent		6	8	4			1
	Absorbing							
Immature		5	10	48	50	4	4	52
Unable to distinguish			1					

TABLE 28. Monthly gonad conditions of yellow perch caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development	25	43	52	17	15	7	
	Mod. development	14	9	1	49	36	36	
	Well developed				6	4	39	3
	Ripe-running							
	Spent	2					1	
Females	Slight development	50	30	46	29	13	5	1
	Mod. development	17	12	4	38	30	38	1
	Well developed	4				3	16	
	Ripe-running							
	Spent	15	2					
	Absorbing							
Immature		30	165	71	48	21	18	1
Unable to distinguish		5	1	3				

great depth found at this station. Night catches of yellow perch at station M were noticeably smaller when compared with day catches, which may reflect a movement of yellow perch into shallower water at night or decreased nocturnal activity. SCUBA observations reported by Jude et al. (1975) indicated that yellow perch were generally inactive at night and hence had lower probability of being gilled.

July -- During July, yellow perch in Lake Michigan appeared most frequently at 6 m and less as indicated by bottom gill net samples (Fig. 47). Yellow perch greater than 175 mm were taken in trawls in July at 6 and 9 m (Fig. 46), which suggests inshore movement also confirmed by first appearance of yellow perch at Lake Michigan beach stations in July. At this time some small (25-45 mm) perch were seined at Lake Michigan beach stations P (s. reference) and Q (s. discharge) (Fig. 48). These perch were probably earlier spawned YOY from Lake Michigan. However, most yellow perch observed in seines at this time exceeded 100 mm in length.

Bottom gill net data from Lake Michigan in July indicated that yellow perch were found near shallower depths (1.5 and 3.0 m) during the night and greater depths (6 m) during the daytime. Jude et al. (1975) found yellow perch in southeastern Lake Michigan exhibited crepuscular movement - inshore at dusk, offshore at dawn.

Bottom gill nets from Pigeon Lake in July contained relatively few perch compared with June catches (Fig. 49), however capture of YOY perch in beach seines at this time increased dramatically (Fig. 50 and Appendix 5), reflecting growth of many of the perch larvae observed in late June larval samples (see FISH LARVAE AND ENTRAINMENT). As in June, catches at beach station T (influenced by Pigeon River) had notably more YOY than catches at other beach stations in Pigeon Lake; however seine catches at stations V (undisturbed Pigeon Lake) and S (influenced by Lake Michigan) exhibited a substantial increase in numbers of YOY yellow perch from June to July (Fig. 50). Highest numbers of larger perch were seined at station S. Decreased catches of larger perch at stations V and T may have been due to the increased vegetation observed there during July. Most adult perch caught at beach stations in Pigeon Lake in June and July ranged in length from 100-200 mm.

August -- August gill nets at Lake Michigan stations indicated that unusually high numbers of larger yellow perch were present at 3 and 1.5 m during the day (Fig. 47), while very low numbers were taken in night gill net sets. Low numbers of large perch caught at beach stations during the day in August may have been due to net avoidance. Due to weather, trawl samples at 3 m could not be performed. However, trawls at 6 m in August (day and night) indicated unusually high densities of YOY yellow perch. Thus it appeared that during August the majority of

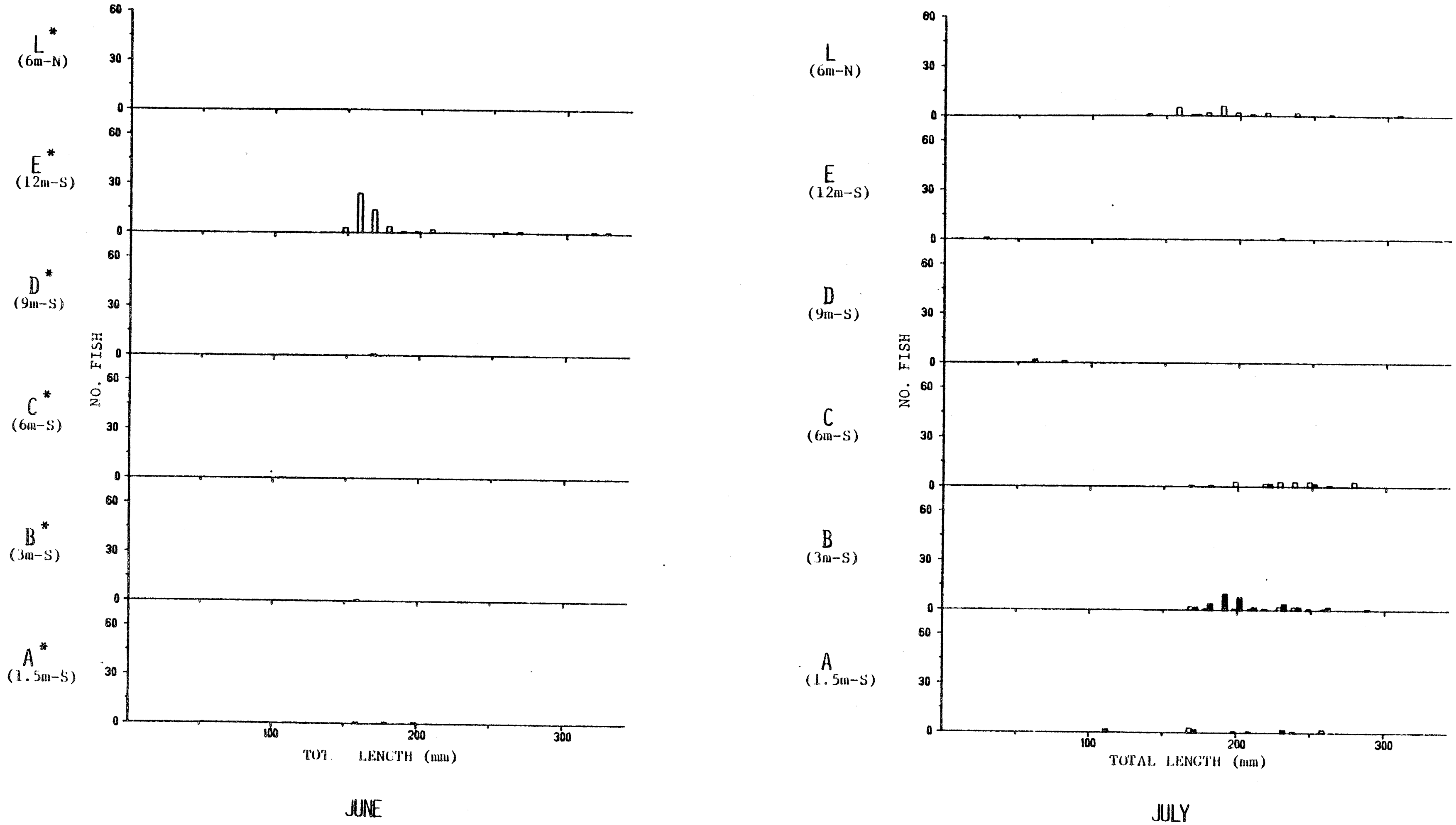


FIG. 47. Length-frequency histograms for yellow perch caught in duplicate bottom gill nets during June to November 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.
* = No night sampling performed.
+ = No sampling performed.

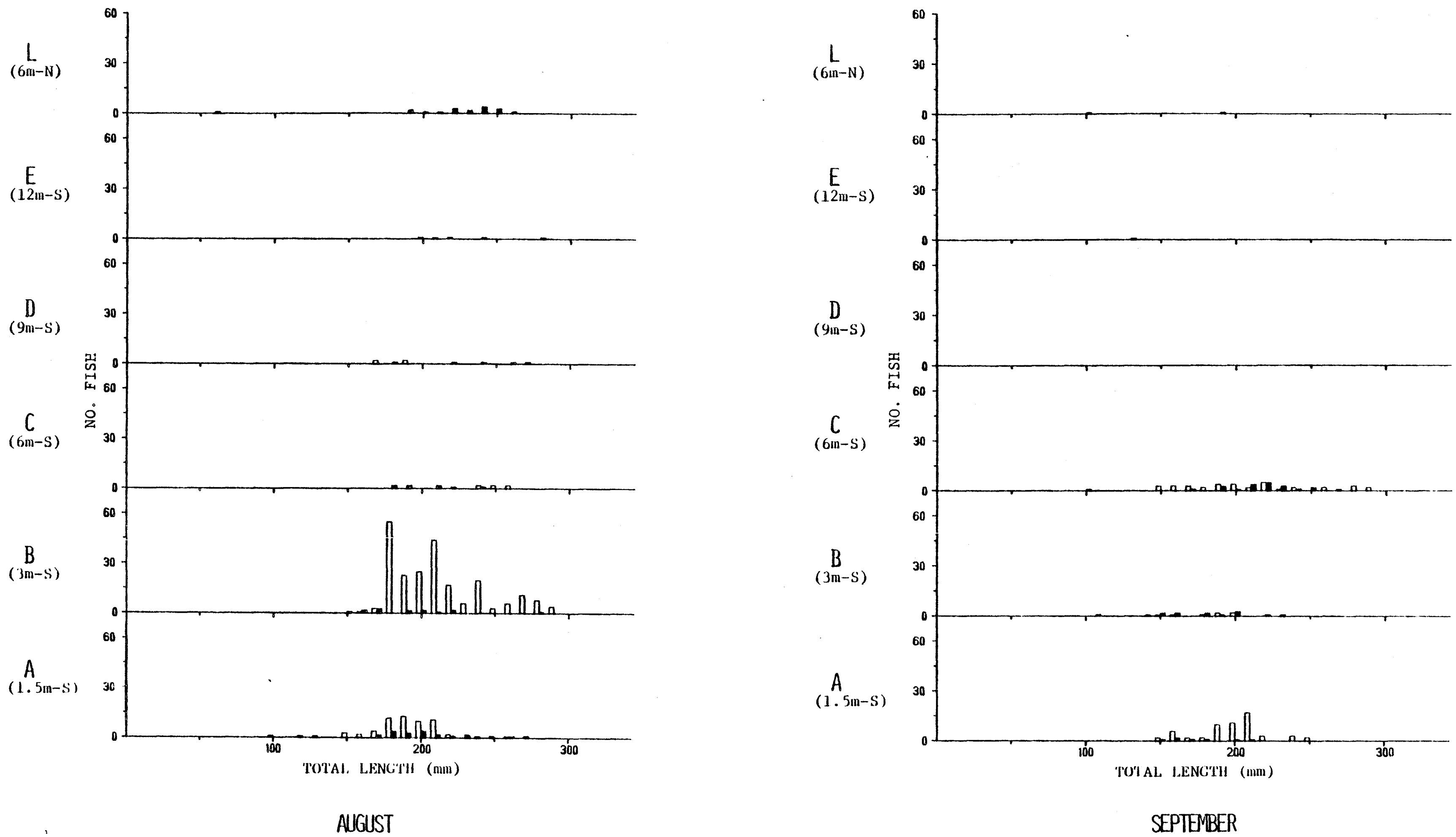


FIG. 47. (Continued)

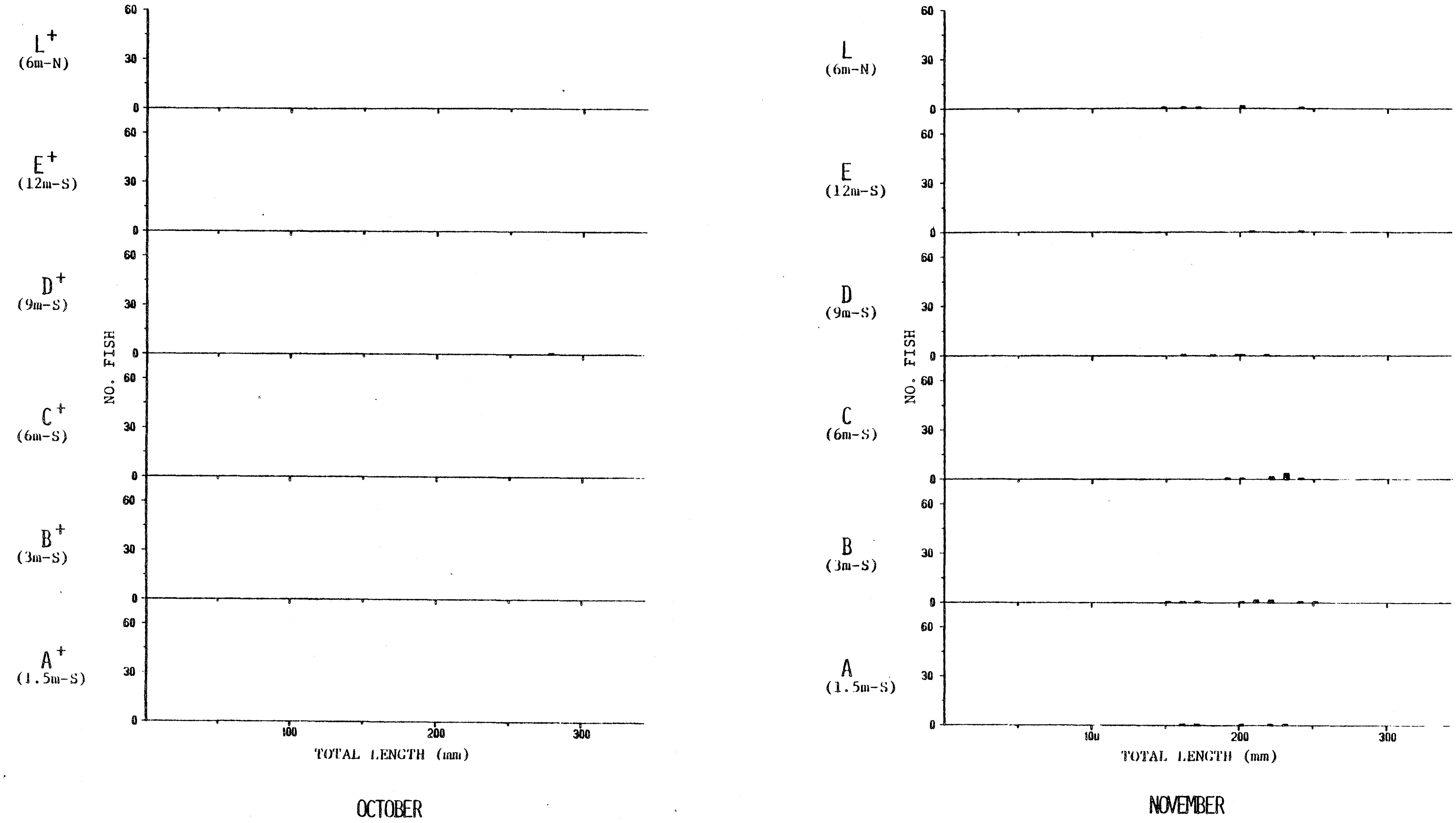


FIG. 47. (Continued)

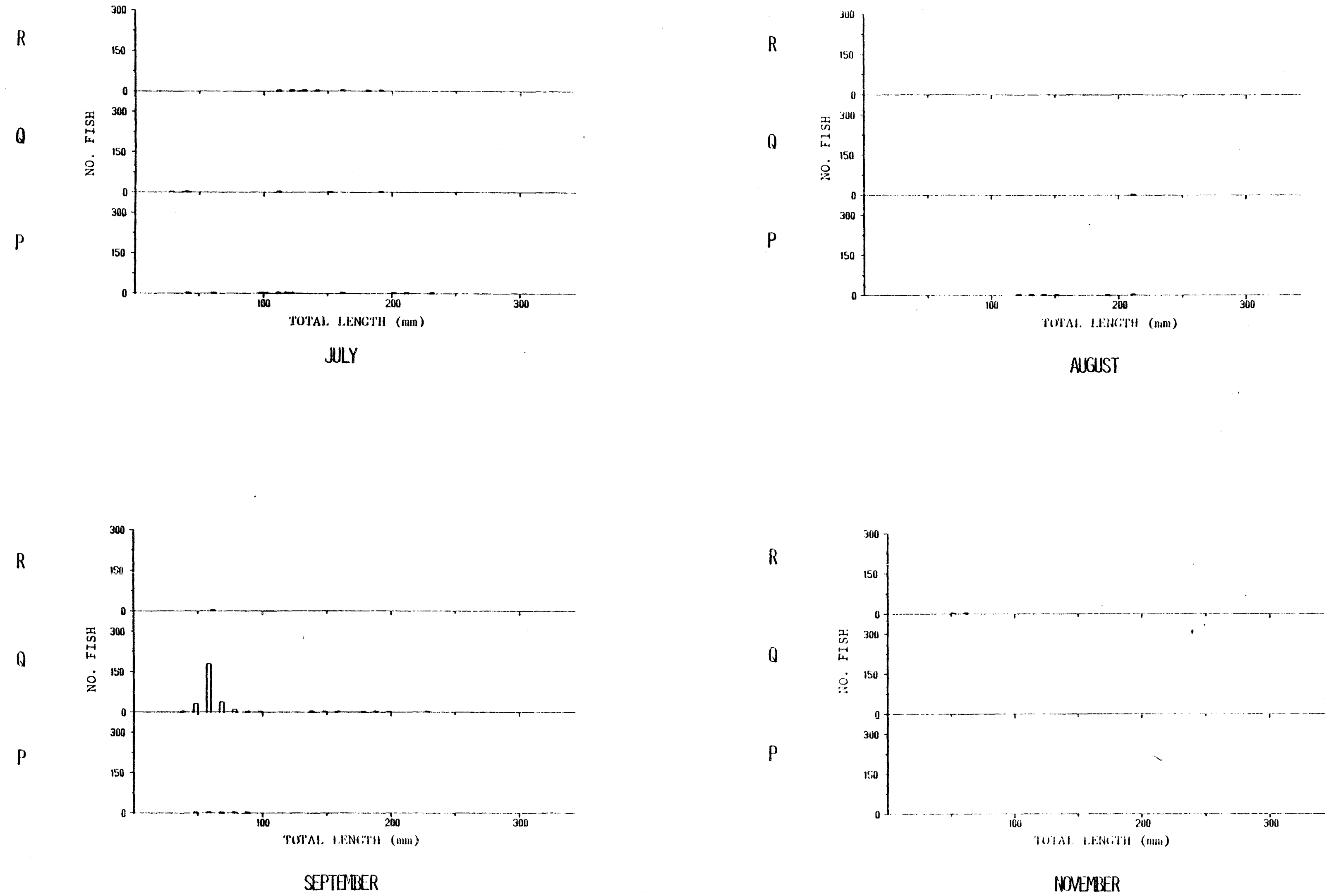


FIG. 48. Length-frequency histograms for yellow perch caught in duplicate seine hauls during July to November 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.

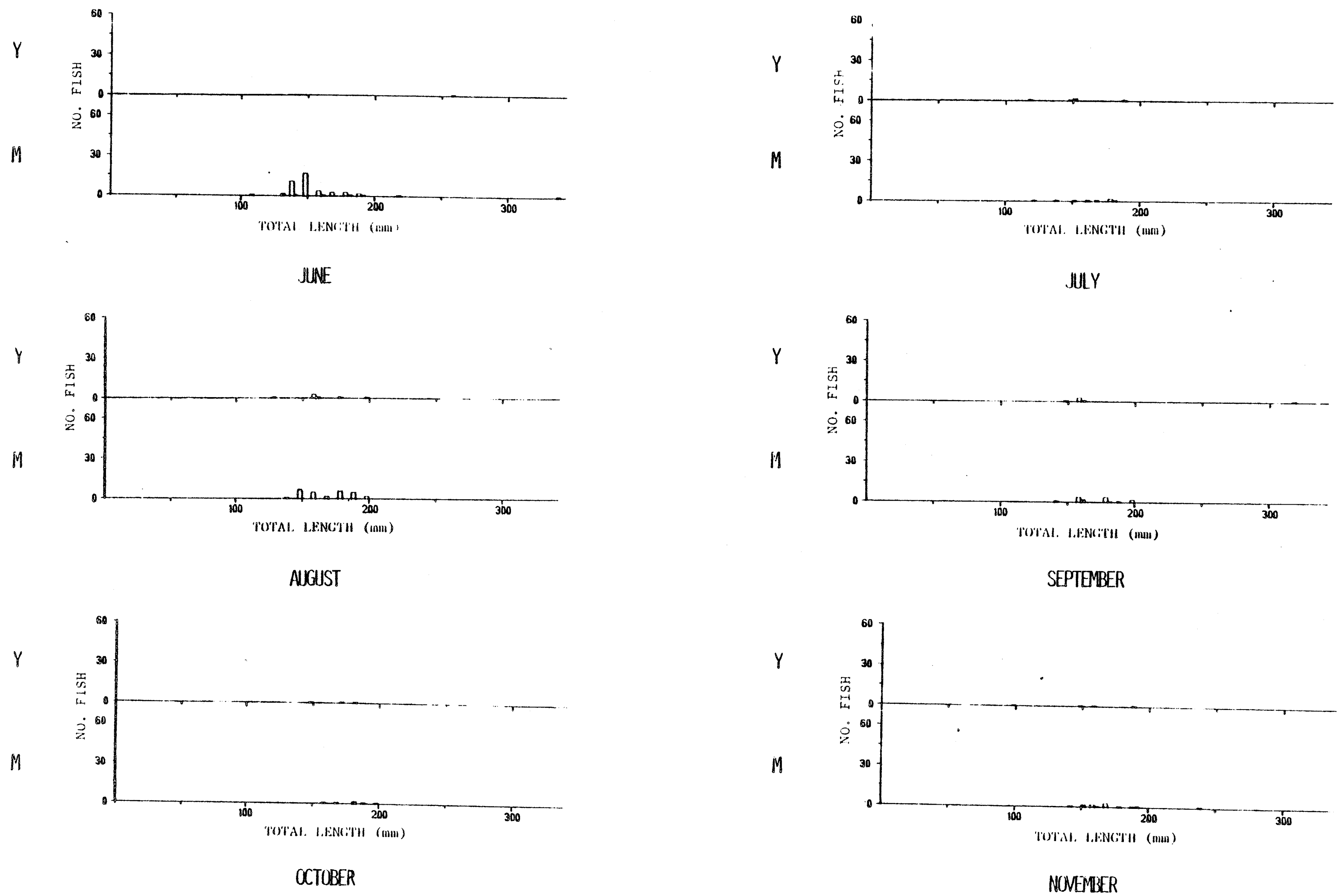


FIG. 49. Length-frequency histograms for yellow perch caught in duplicate bottom gill nets during June to December 1977 in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.

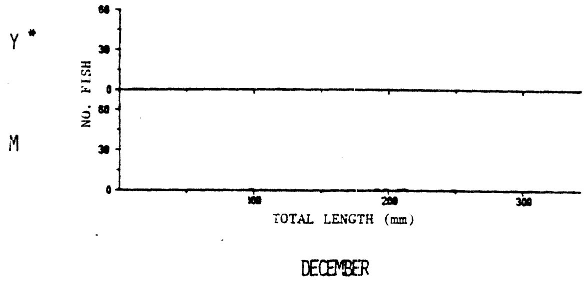


FIG. 49. (Continued)
* = No night sampling performed.

the perch population was inshore at depths of 1.5 - 6 m. Examination of gill net catches of adults in August (Fig. 47) confirmed that yellow perch were generally more active during daylight hours as compared with night.

In Pigeon Lake decreased numbers of YOY yellow perch were observed at all beach stations compared with July catches. Increased ability of small perch to avoid the net as well as mortality and dispersal were probably responsible for the decreased numbers of YOY observed. As in July more YOY were observed at station T (influenced by Pigeon River) in August than at other Pigeon Lake beach stations.

Pigeon Lake bottom gill nets in August caught increased numbers of adults at station M (influenced by Lake Michigan) compared with July, while numbers of fish caught at station Y (influenced by Pigeon River) in August were comparable to those observed in July.

September -- Numbers of yellow perch caught in trawls and gill nets (Figs. 46 and 47) at Lake Michigan stations decreased in September compared with August, but adults remained concentrated in water depths less than 9 m. Trawl samples also showed somewhat higher numbers of YOY at 6 m and 3 m, compared with other depths although numbers of YOY had declined considerably, compared with August especially at station L (6 m - n.). Relatively high numbers of YOY were however found at beach station Q (s. discharge) (Fig. 48). The reason for this high catch may be related to water temperature. September day temperature at beach station Q (s. discharge) was 15.6 C compared with 12.2 C at station R (n. discharge). Higher water temperatures may have attracted perch to the area near station Q. During night seine hauls at station Q water temperature dropped to 10.0 C and few perch were observed in the area.

In general catch of yellow perch in Pigeon Lake in September was comparable to August with a few exceptions. The number of YOY seined at station V (undistrubed Pigeon Lake) declined in September compared with August. Stations T (influenced by Pigeon River) and S (influenced by

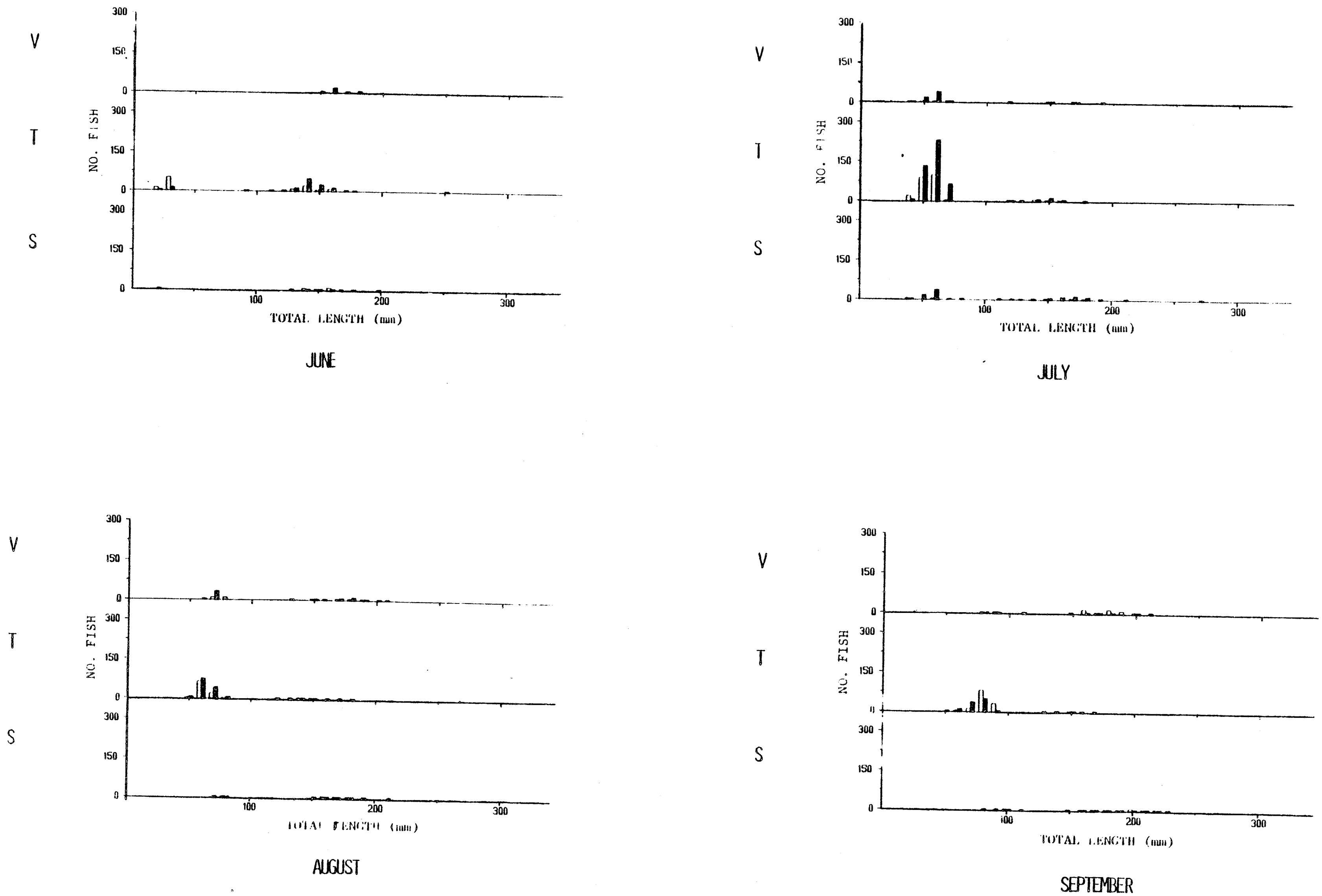
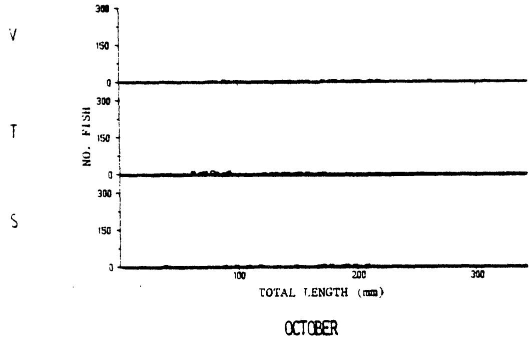


FIG. 50. Length-frequency histograms for yellow perch caught in duplicate seine hauls during June to November 1977 in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan.
□ =day ■ = night.



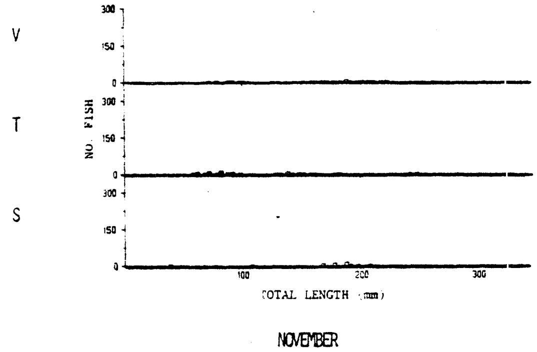


FIG. 50. (Continued)

Lake Michigan) had catches comparable to those taken in August. Station T continued to have the highest catches compared with other Pigeon Lake beach stations. Slight decreases in gill net catches were observed at station M (influenced by Lake Michigan) in September when compared with August. Gill net catches of perch at station Y (influenced by Pigeon River) in September were comparable to those recorded in August.

October -- Dramatic decreases were observed in yellow perch catches from all gear types used at Lake Michigan stations in October. No perch were present in the beach zone since none were caught in beach seine hauls. No gill nets were set in Lake Michigan during October. YOY occurred sporadically in Lake Michigan trawls during October with three being caught at 6 m and one at 15 m. Two larger yellow perch (160 and 167 mm) were caught at deep (12 and 15 m) stations. It was evident that offshore migration of adults had occurred by the time October sampling commenced. Jude et al. (1975) observed that offshore migration of yellow perch had occurred in September during 1974 in southeastern Lake Michigan.

In Pigeon Lake during October station T was again the most productive area for YOY perch (Fig. 50). However these catches were substantially lower than in September. This decline may be due to natural mortality or more likely an age-related dispersal of YOY yellow perch from their rearing area as they grew older. Pigeon Lake beach station V (undisturbed Pigeon Lake) and beach station S (influenced by Lake Michigan) collections showed numbers of perch comparable to September catches. A slight decline in the number of large yellow perch caught in bottom gill nets at Pigeon Lake station M (influenced by Lake Michigan) and Y (influenced by Pigeon River) during October (Fig. 49) was observed.

November -- Bottom gill net samples taken during November from Lake Michigan indicated that adult yellow perch were most frequently caught in water less than 12 m (Fig. 47). Trawl data for November corroborated this distribution (Fig. 46) as YOY yellow perch were also trawled at 6 and 9 m. No night trawling was performed at 3, 18 and 21 m. Beach

seine hauls at Lake Michigan stations in November contained some YOY yellow perch at station R (n. discharge), but no adults. These data, in addition to zero catch in beach seines in October, probably indicated that the beach zone was abandoned by yellow perch in colder months.

In contrast yellow perch were still moderately abundant at all beach stations (particularly station T) of Pigeon Lake (Fig. 50). Interestingly enough, adult and yearling perch caught in the densely vegetated, protected habitat of station T, were consistently smaller than perch caught at other Pigeon Lake beach stations.

Gill nets in Pigeon Lake contained numbers of perch comparable to October values (Fig. 49). More larger yellow perch were caught at station M (influenced by Lake Michigan) than were caught at station Y (influenced by Pigeon River).

December -- December sampling in Lake Michigan was restricted to trawling, (out to the 15 m station) and indicated YOY perch were present in the area from 3-12 m. Absence of adult perch at the 3 to 12 m depth contours, with the exception of one caught at station L (6 m - n.), was indicative of their movement to deeper water. Jude et al. (1979) found that while adult yellow perch left the inshore zone and went to deeper water (deeper than 9 m) in winter months, YOY remained in shallower water.

Only gill net sampling was performed in Pigeon Lake during December. No yellow perch were caught (only day nets were set) at station Y (influenced by Pigeon River), while some adult perch were collected at station M (influenced by Lake Michigan) (Fig. 49).

<u>Temperature-Catch Relationships</u> -- Water temperature at time of capture for any one size group of yellow perch varied considerably. Larger fish tended to be captured at lower water temperatures in both lakes (Fig. 51). Findings of McCauley and Read (1973) supported the contention that age played an important role in temperature selection by this species. Older fish selected cooler temperatures than younger perch acclimated to the same temperature. Jude et al. (1979) noted that smaller perch (60-120 mm) were most often caught at water temperatures 16-19 C and larger perch (230-330 mm) at 14-17 C.

<u>Other Considerations</u> -- Abundance of yellow perch caught by trawling in the area of the Campbell Plant varied according to month, with significantly higher catches in August, September and December (see STATISTICS). The increased number of perch caught in August was undoubtedly the result of YOYs recruited to the population vulnerable to the trawl samples. Recurrence of increased YOY numbers was observed in December when YOY apparently remained at 3-12 m and possibly overwintered there. Jude et al. (1979) found in southeastern Lake

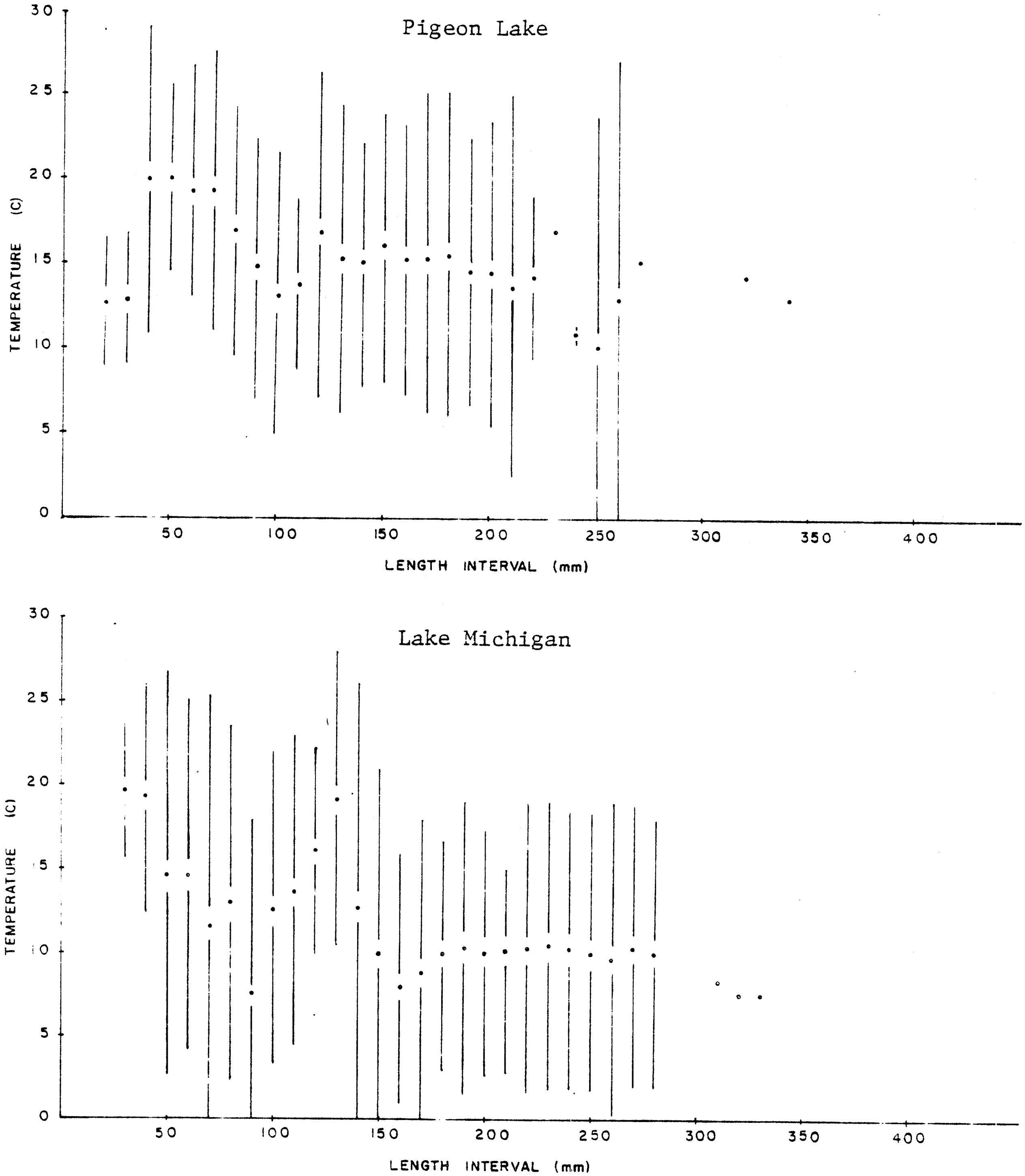


FIG. 51. Weighted-mean temperatures for 10 mm length intervals of yellow perch caught by all gear types from Pigeon Lake and Lake Michigan in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1977. Vertical lines represent ± 2 standard deviations.

Michigan that the bulk of the YOY remained in water deeper than 9 m in colder months, but some of the YOY population remained inshore in early winter. The increased number of yellow perch observed in September was primarily due to larger fish (>150 mm) which were in water 6 m and less at this time. Yellow perch usually exhibit an offshore movement to deeper water in autumn. Jude et al. (1979) suspected that in southeastern Lake Michigan during winter and spring, the bulk of the adult population was at depths somewhat greater than 9 m, but schools of perch enter the shallower depths (6 m or less) during the day. No night trawling was performed in September to compare with day trawls, but schools of perch moving into shallow water (3 m) during daytime may be a reason for the higher catch of adults in day trawls in September.

Diel differences in trawl catches of yellow perch in the area of the Campbell Plant during 1977 were not significant. Jude et al. (1975) reported that from June to August in southeastern Lake Michigan yellow perch were more vulnerable to trawls during the day than at night.

Summary -- Yellow perch were abundant in the area of the J. H. Campbell Plant ranking fourth numerically in catches of adult fish in both Lake Michigan and Pigeon Lake. Seasonal changes in abundance of yellow perch in the surrounding Lake Michigan area, were similar to those observed by other researchers in southeastern Lake Michigan. Yellow perch moved inshore in late spring for spawning. During summer, there was some indication of a nocturnal offshore movement and an inshore movement during the day. Perch remained within the sampling depths (0-18 m) until late autumn when there was an apparent movement of adults to more offshore water. December sampling indicated that YOY remained within the sampling area until and possibly throughout the winter.

Pigeon Lake appeared to sustain a considerable population of yellow perch. Spawning time of yellow perch in Pigeon Lake was found to occur earlier than in Lake Michigan and probably commenced in April during 1977. YOY comprised the majority of perch caught in Pigeon Lake throughout our sampling period and indicated extensive use of that area for spawing and as a nursery. Adult yellow perch were generally more abundant in the easily seined shoreline compared with the openwater gill net stations.

Golden Shiner --

Introduction -- Golden shiners live in clear, weedy quiet water with extensive shallow areas. This species swims actively in schools, covering large areas just off the bottom (Scott and Crossman 1973). They feed at mid-water or the surface and help control mosquitoes to some extent (Becker 1976). The golden shiner is endemic to much of North America east of the Dakotas and Texas and south of the Canadian

Maritime Provinces. It has been introduced to many other areas, especially the western United States.

<u>Seasonal distribution</u> -- The golden shiner was the third most numerous fish caught in Pigeon Lake making up 12.6% by number of the fish captured. None were collected in Lake Michigan. In all, 2615 golden shiners were collected from June through November (Tables 13 and 14). These fish ranged in length from 23 to 170 mm, with most between 40 and 100 mm. Only 11 golden shiners were gillnetted in Pigeon Lake (Fig. 52 and Table 19). All were caught in the Pigeon River area of the lake at station Y; none were collected at station M (influenced by Lake Michigan). Generally only the larger specimens (>100 mm) were caught in gill nets. Seining at Pigeon Lake beach stations resulted in the capture of the remaining 2604 golden shiners taken and appeared to be the most efficient means of sampling. Most golden shiners (92%) were seined at station T (influenced by Pigeon River), with the remainder being seined at stations S (influenced by Lake Michigan) and V (undisturbed Pigeon Lake) (Fig. 53).

Sampling in June indicated that moderate numbers of adult golden shiners were at beach station T (influenced by Pigeon River). Absence of ripe and ripe-running adult golden shiners in June samples (Table 29) suggested the possibility that spawning of this species had occurred prior to our sampling. Spawning by golden shiners in the area had occurred, since larvae were found in late June and July larvae samples (Appendix 8).

Golden shiners usually spawn from June to August when water temperatures reach 20 C (Becker 1976). Some mature by their second summer when they have attained a length of 64-89 mm (Scott and Crossman 1973). This species scatters and abandons eggs over filamentous algae (Scott and Crossman 1973). Rooted vegetation will suffice in the absence of filamentous algae but some type of aquatic vegetation is necessary.

YOY golden shiner began to appear in substantial numbers at beach station T (influenced by Pigeon River) in July. As with other minnows (e.g. bluntnose minnow) it appeared that this station was the most suited of the three Pigeon Lake beach stations for spawning and rearing of young. Some spawning at other Pigeon Lake beach stations was indicated by the presence of low numbers of YOY in July (Fig. 54). Catches of YOY declined in August and again in September. These declines were probably due to natural processes of mortality, predation and dispersal. At this time there was also an increase in the size of YOY which may have coincided with an increased ability to avoid our nets. Macrophyte cover in the area had also appreciably declined, a factor which would assist fish in avoiding a net.

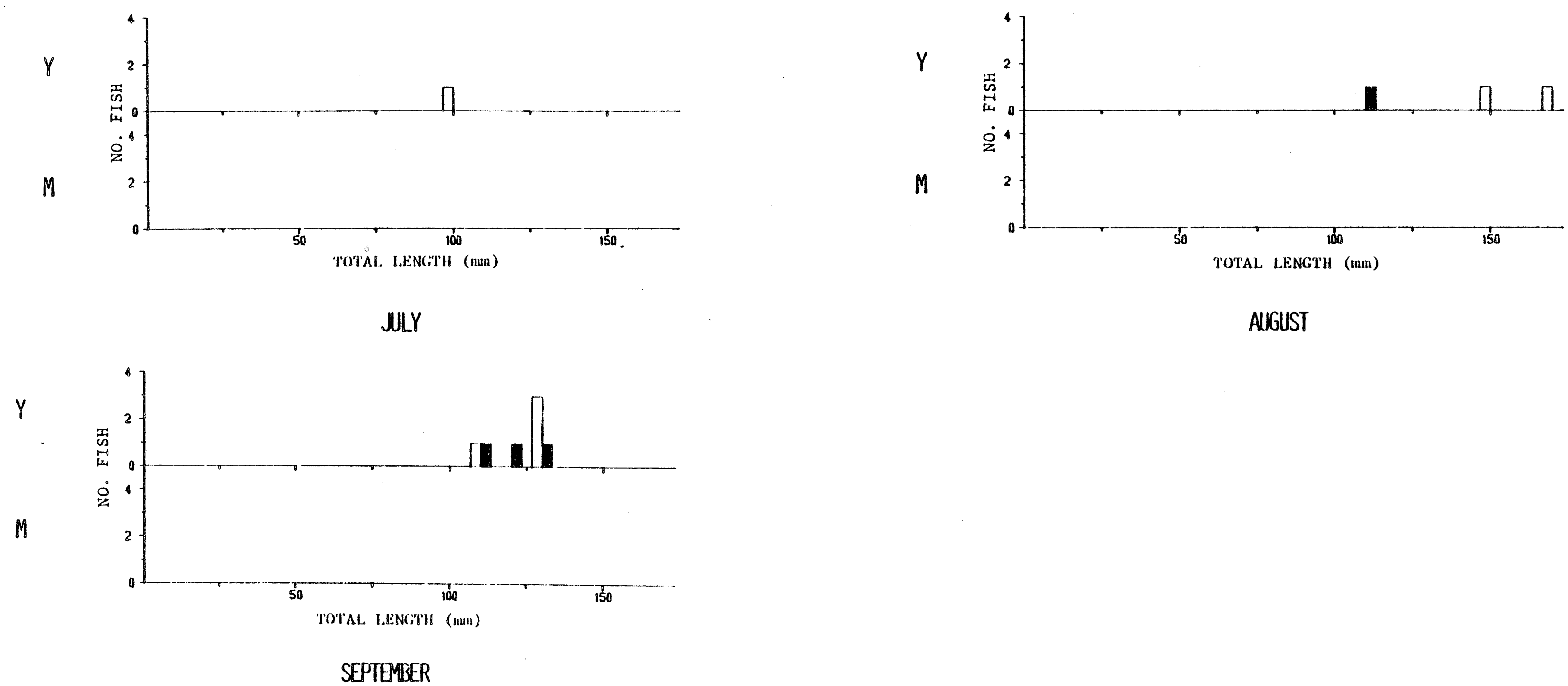


FIG. 52. Length-frequency histograms for golden shiner caught in duplicate bottom gill nets during July to September 1977 in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.

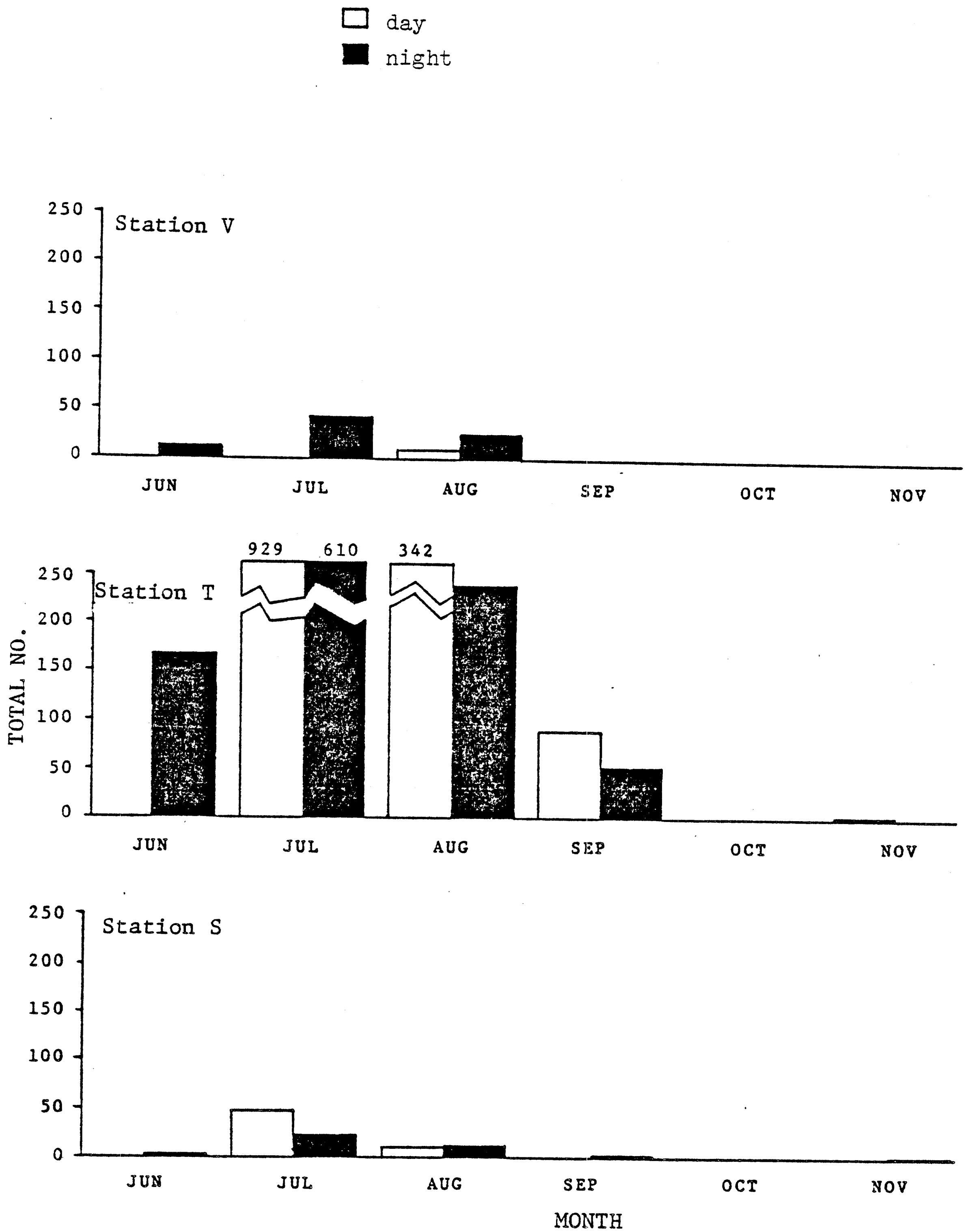


FIG. 53. Total number of golden shiner caught in duplicate seine hauls in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, June - November 1977.

TABLE 29. Monthly gonad conditions of golden shiners caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development		21	29	5			
	Mod. development		2					
	Well developed							
	Ripe-running							
	Spent							
Females	Slight development	1	10	8	4			
	Mod. development		4		3			
	Well developed							
	Ripe-running							
	Spent							
	Absorbing							
Immature		2	87	61	31		1	
Unable to distinguish		2	24	10	4		1	

As with many species of minnows (e.g. bluntnose minnow and spottail shiner) cooler water temperatures caused a movement from the shallow easily seined water into deeper sections of the lake. This movement into deeper water was suggested by the increased number of larger golden shiners which were observed in gill nets during September (Fig. 52). During October there was an absence of golden shiners at beach stations in Pigeon Lake, indicating that movement of this species into deeper water was probably complete.

Other considerations -- Examination of temperature-catch relationships for golden shiners (Fig. 55), showed that fish of all length ranges were collected at about the same water temperatures, from about 15 to 25 C. A few small fish were seined when the water temperature was around 11 C.

Summary -- Golden shiners were the third most abundant species caught in Pigeon Lake. Spawning was assumed to have occurred in May (before our sampling began), and took place primarily near beach station T (influenced by Pigeon River). Substantial numbers of YOY appeared in July seine samples and then declined in subsequent months as the effects of dispersal, natural mortality and predation were manifested. Adult golden shiners appeared to occupy deeper water except when they moved

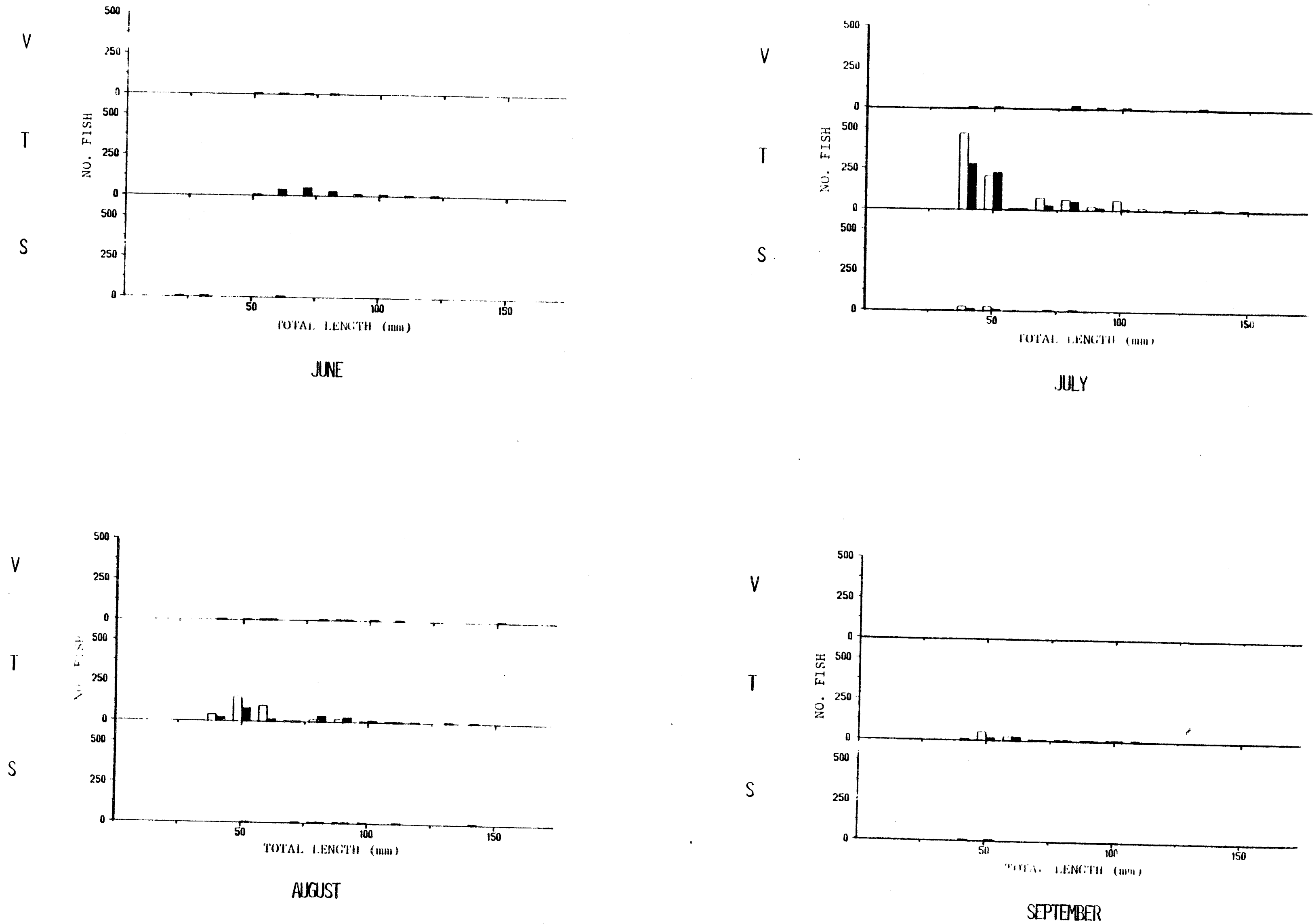


FIG. 54. Length-frequency histograms for golden shiner caught in duplicate seine hauls during June to November 1977 in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.

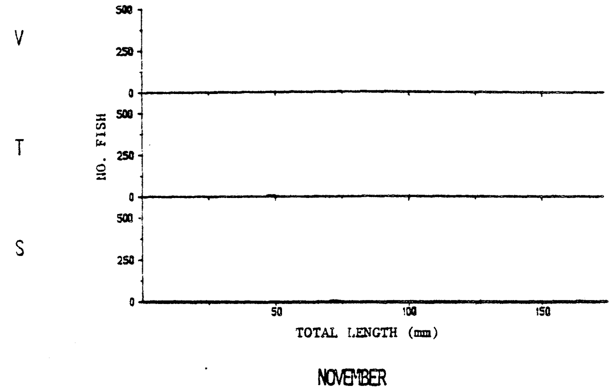


FIG. 54. (Continued)

inshore during the spawning season. No diurnal activity patterns could be determined from our data and little correlation between length of fish and water temperature at which they were caught was observed.

Bluntnose Minnow --

<u>Introduction</u> -- The bluntnose minnow is native to much of central North America, including the Mississippi and Great Lakes drainages (Scott and Crossman 1973). Although bluntnose minnows are uncommon in the openwater of Lake Michigan, the slow moving, soft-bottom nature of Pigeon Lake provides an excellent habitat for propagation and survival of this species.

Spawning of the bluntnose minnow occurs in 0.3-1 m of water during May or June. Adhesive eggs are laid on the undersurfaces of stones and other objects. Hatching takes place in 1-2 wks (depending on water temperature), and larvae may attain a length of 12 mm within 2 wks (Westman 1938).

Preliminary observations of piscivorous fish stomachs in Pigeon Lake indicated the bluntnose minnow served as forage for a number of species including northern pike, largemouth bass, yellow perch, grass pickerel, bowfin and sunfishes. Bluntnose minnows are reported to feed primarily on organic detritus and bottom ooze (Heufelder 1976).

<u>Seasonal distribution</u> -- All bluntnose minnows in the present study (1560 fish-7.5% of total catch) were caught by seine at Pigeon Lake beach stations. The apparent absence of bluntnose minnow from deep water stations in Pigeon Lake was probably due to inefficiency of our gill nets to sample this minnow. Bluntnose minnows occurred in collections at all Pigeon Lake beach stations in June (Fig. 56). At this time, most specimens caught were greater than 46 mm in length; most were caught at night. Higher catches at night during June were probably

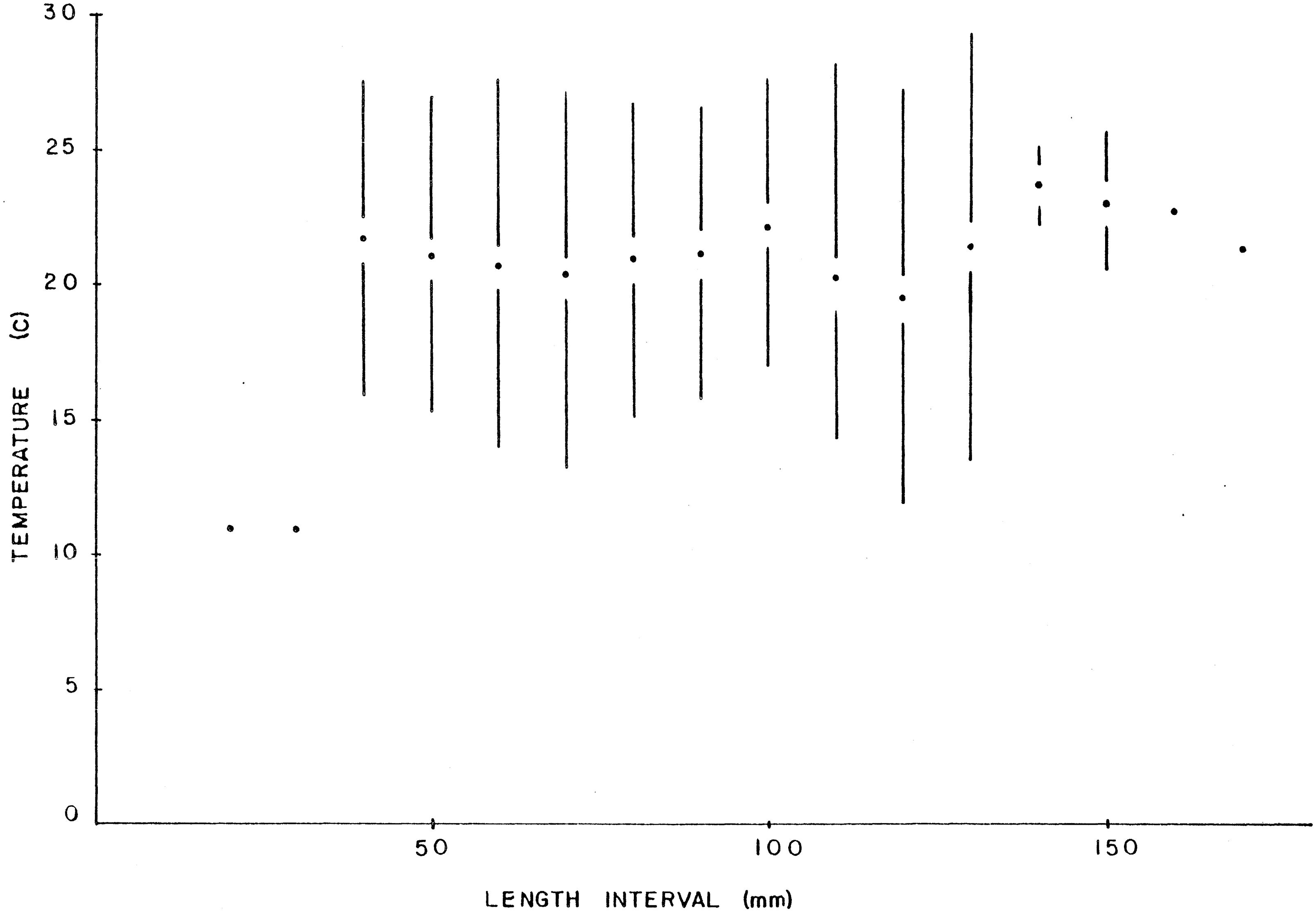


FIG. 55. Weighted-mean temperatures for 10 mm length intervals of golden shiners caught by all gear types from Pigeon Lake in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1977. Vertical lines represent $\pm$ 2 standard deviations.

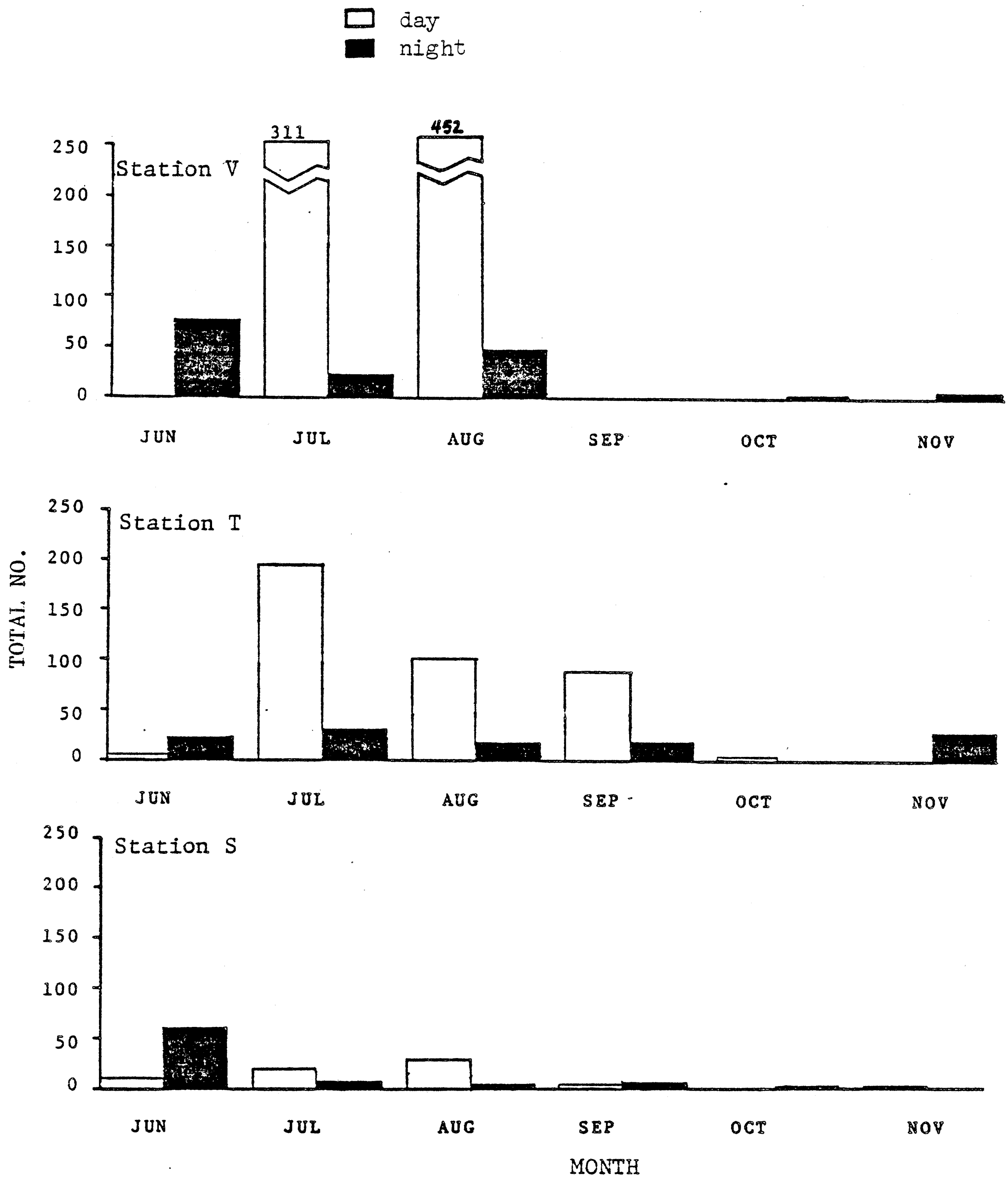


FIG. 56. Total number of bluntnose minnow caught in duplicate seine hauls in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, June - November 1977.

TABLE 30. Monthly gonad conditions of bluntnose minnows caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development		3	10		1	1	
	Mod. development		4					
	Well developed							
	Ripe-running							
	Spent							
Females	Slight development		4	2				
	Mod. development		2					
	Well developed	1	2					
	Ripe-running	2						
	Spent		1					
	Absorbing							
Immature		13	54	101	24	2	2	
Unable to distinguish			14	10		1		

related to the nocturnal spawning activity of this species documented by Westman (1938). Presence of bluntnose minnow larvae in our field larvae samples taken in June (Appendix 8) indicated that spawning in Pigeon Lake began in late April. Gonad data (Table 30) suggested that spawning continued through July. Highest numbers of adult bluntnose minnows in June were caught at beach stations V (undisturbed Pigeon Lake) and S (influenced by Lake Michigan), with somewhat lower numbers caught at station T (influenced by Pigeon River) (Fig. 56).

July seine hauls were in sharp contrast to June seine hauls as the majority of bluntnose minnows were seined in the daytime. Relatively lower nocturnal catches of bluntnose minnows from beach stations in July may indicate, a nocturnal movement to deeper water. Increased numbers of bluntnose minnows were observed at stations V and T, while lower numbers were observed at station S. Length-frequency data (Fig. 57) indicated that a substantial part of the increased number of bluntnose minnows collected at station V and T in July was due to recruitment of 26-35 mm fish to the population of bluntnose minnow vulnerable to seines. These fish were probably YOY.

Reasons for the dearth of YOY bluntnose minnows at station S (influenced by Lake Michigan) in July are unclear. Station S may not

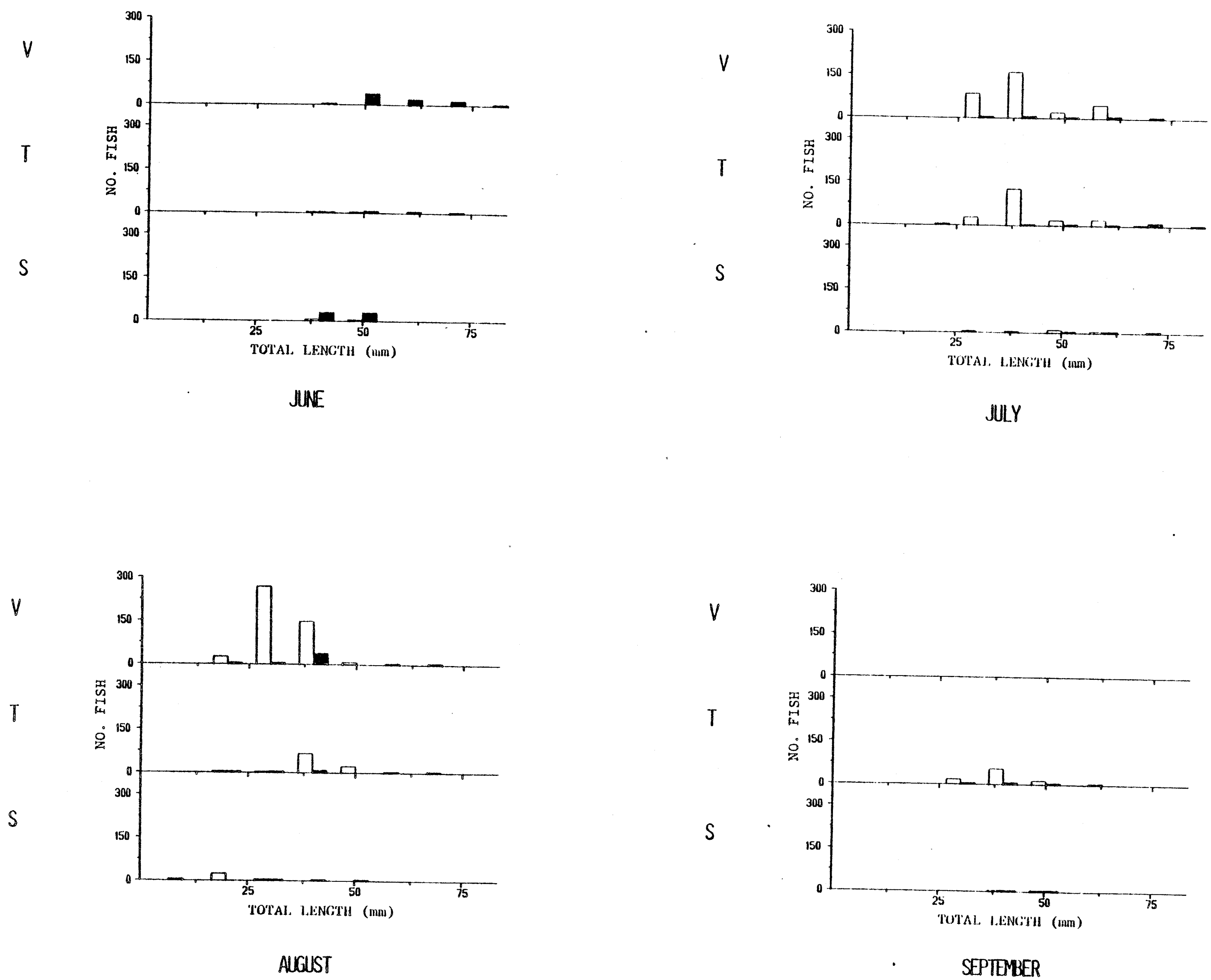


FIG. 57 Length-frequency histograms for bluntnose minnow caught in duplicate seine hauls during June to November 1977 in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan. □ = day ■ = night.

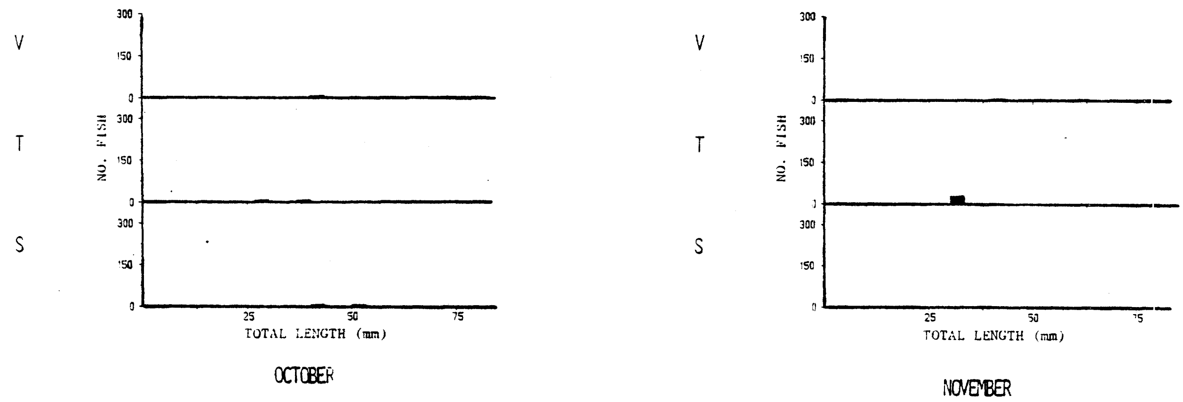


FIG. 57. (Continued)

afford necessary cover for successful bluntnose minnow rearing; hence predation and natural mortality caused the lower numbers of YOY observed in our samples. It is also possible that spawning occurred later at this station. Temperatures during June and July were lower at station S than at other Pigeon Lake beach stations, which may have retarded spawning of bluntnose minnows in the area. August field collections substantiated the latter possibility as YOY bluntnose minnows smaller than 25 mm were observed in seine catches at station S.

Highest monthly catch of bluntnose minnows, 653 fish, was recorded in August (Appendix 4). Most of the catch was comprised of YOY because of their recruitment to the sampled population. Larger numbers than observed in July were caught at station V, while a decline in the numbers of 36-45 mm bluntnose minnows occurred at station T. As during July, August seine hauls in Pigeon Lake showed that more bluntnose minnows were at easily seined depths during the day than at night, further confirming movement of this minnow into deeper water at night.

Absence of bluntnose minnows from seine hauls at station V in September may be due to a movement of fish from this area to deeper water. This movement was also suspected for golden shiners in September (see ADULT AND JUVENILE FISH, Golden Shiner). Numbers of bluntnose minnows caught at station T (influenced by Pigeon River) and S (influenced by Lake Michigan) in September were comparable to August values (Fig. 57) indicating no movement of fish from these areas as yet.

Low numbers of bluntnose minnows were present at all beach stations in October. Most bluntnose minnows had probably moved from areas of shallow water to deeper water. Length-frequency data showed that those remaining in the beach zone were primarily YOY (Fig. 57).

In November the only substantial concentration of bluntnose minnows was found at beach station T with lower numbers at station V (Fig. 57). Many of these fish were also YOY, which apparently exhibited a tendency

to remain in shallow water perhaps throughout the winter.

<u>Temperature catch relationships</u> -- Bluntnose minnows were caught at a wide range (8.0-26.5 C) of temperatures. There was some tendency for smaller bluntnose minnows to be caught at higher temperatures (Fig. 58).

<u>Summary</u> -- The bluntnose minnow was the fifth most common fish collected in Pigeon Lake with numbers fluctuating in the shallow areas in a manner similar to spottail and golden shiner. Adult bluntnose minnows were only caught in Pigeon Lake at beach stations. They were observed in June at all beach stations, when their primarily nocturnal occurrence was probably related to spawning behavior. During July to August seine catches were dominated by YOY and it became evident that Pigeon Lake beach stations V and T, both of which are removed from the influence of Lake Michigan, were more conducive to the spawning and rearing of bluntnose minnows. Most adults moved from the shallows by autumn; however, YOY were still observed in the beach zone near the Pigeon River in November. Bluntnose minnows seemed to be an important component of the forage species in Pigeon Lake.

Trout-perch --

<u>Introduction</u> -- Trout-perch are widely distributed in central and northern North America (Scott and Crossman 1973). They are found in the shallow water of Lake Michigan and in the lower extremities of its larger tributaries and become more common northward (Becker 1976).

Trout-perch feed on a variety of aquatic insect nymphs, amphipods, copepods and several other kinds of small crustaceans. They are small, bottom dwellers without any commercial or recreational value, but can serve as an important forage species as shown in Lower Red Lake (Magnuson and Smith 1963), Lake Erie (Kinney 1950) and Heming Lake, Manitoba (Lawler 1954).

Various aspects of trout-perch life history were investigated in western Lake Erie (Kinney 1950), in Lake Superior (Bostock 1967) and in Lower Red Lake, Minnesota (Magnuson and Smith 1963). In Lake Michigan, the first published information on this species consisted of a description of its seasonal depth distribution, based on experimental trawling data (Wells 1968). A study on its age, growth and spawning was performed on samples trawled from several areas in southeastern Lake Michigan (House and Wells 1973). More recently, Jude et al. (1975) conducted an extensive study on the biology of trout-perch, using samples collected by trawl, gill net and seine near the Cook Plant, southeastern Lake Michigan.

Trout-perch are a relatively abundant species near the J. H.

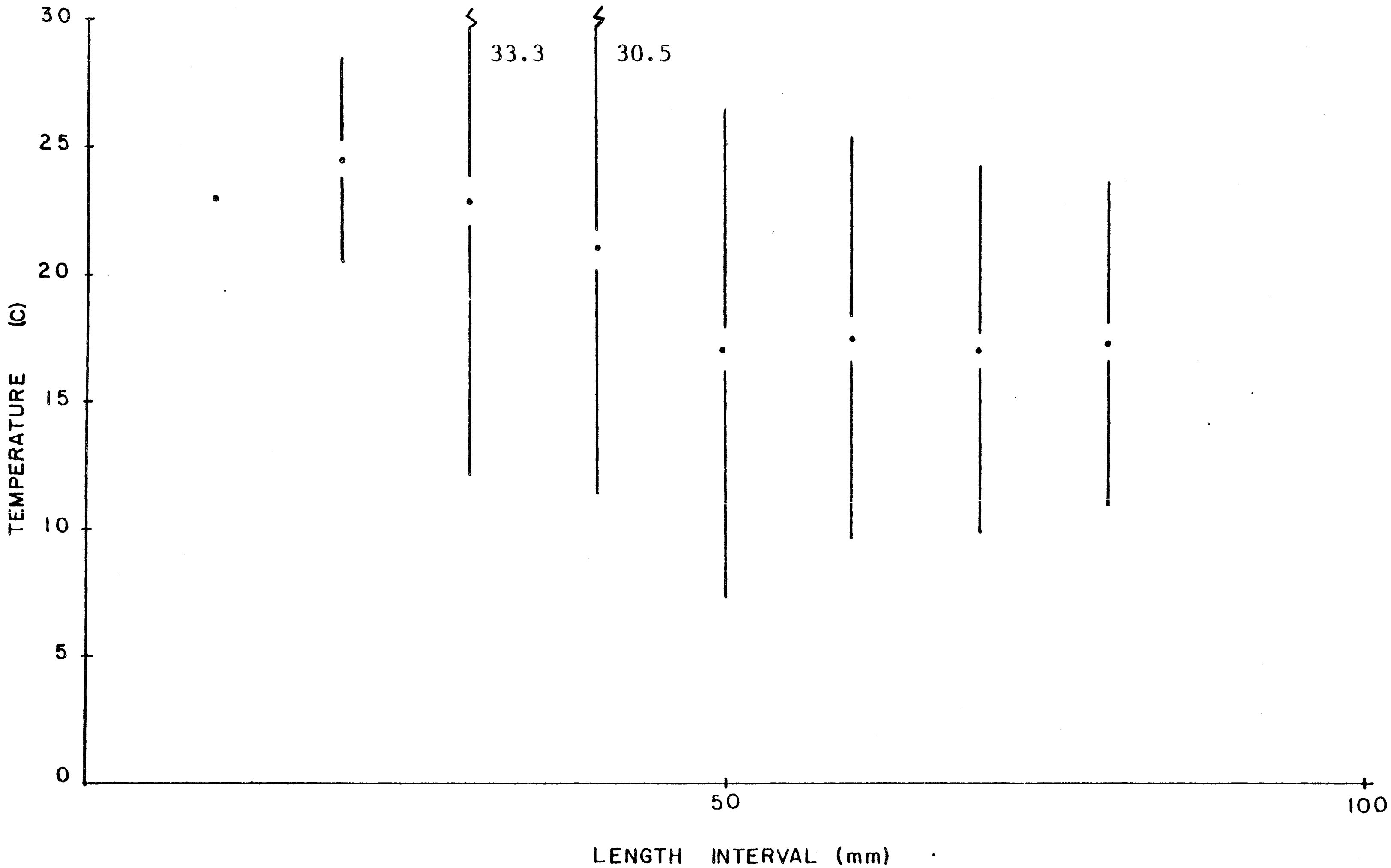


FIG. 58. Weighted-mean temperatures for 10 mm length intervals of bluntnose minnows caught by all gear types from Pigeon Lake in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1977. Vertical lines represent $\pm$ 2 standard deviations.

Campbell Plant. They were caught mostly from Lake Michigan and accounted for approximately 1.14% of the total catch from this lake (Table 13). Only a few trout-perch were collected from Pigeon Lake. The major portion of the Lake Michigan catch was obtained by trawl; gill nets and seines contributed only a small portion of the trout-perch catch.

Seasonal Distribution -- Trout-perch live in deep water during the colder months and migrate to inshore areas in spring and summer. Wells (1968) found most trout-perch in Lake Michigan between 23 and 32 m in February. In Lake Superior, they remained in water deeper than 64 m during winter and early spring (Bostock 1967). The inshore movements in southeastern Lake Michigan began in April, increased through May and reached a peak in June (Jude et al. 1975). During summer months, trout-perch were found mostly at the 9 and 12 m contours in Lake Michigan (Wells 1968) and in water less than 27 m deep in Lake Superior (Bostock 1967).

June -- As our sampling program did not start until June, data from previous months were lacking. Peak catch of trout-perch occurred in June (Appendix 4 and Fig. 59). Trawling was the most productive fishing method and captured trout-perch at all stations sampled (Appendix 5 and Fig. 60). Most trout-perch were caught between 6 and 15 m. Only a few specimens were collected at 18 and 21 m (Fig. 60), suggesting that the bulk of the trout-perch population remained within the 15 m contour in June. Trawling was not performed at 3 m, but the catch of four trout-perch by seine (Fig. 61) indicated that the distribution of this fish extended to the beach zone. Because of bad weather no bottom gillnetting was completed at night. The day set did not capture any trout-perch. Compared to the pattern of seasonal migration of trout-perch described in other studies (Bostock 1967, Jude et al. 1975), our data suggested that June was the peak period of trout-perch inshore movements which probably started in April or May.

More trout-perch in June were caught at night than during the day at all stations except for station F (15 m - s.). Trout-perch have been observed to move inshore at night to spawn in the shallows of lakes or lower reaches of streams (Magnuson and Smith 1963, Scott and Crossman 1973). Presence of ripe adults and of larval trout-perch (see FISH LARVAE AND ENTRAINMENT) in the inshore water of Lake Michigan near the Campbell Plant suggested that spawning occurred during at least June in the area.

Trout-perch spawned from May to August in Lower Red Lake, Minnesota (Magnuson and Smith 1963) and from June to August in Lake Erie (Kinney 1950) and in southeastern Lake Michigan (Jude et al. 1975). In 1972, however, spawning of this species in Lake Michigan was slightly delayed; it started in late June and extended through August (House and Wells

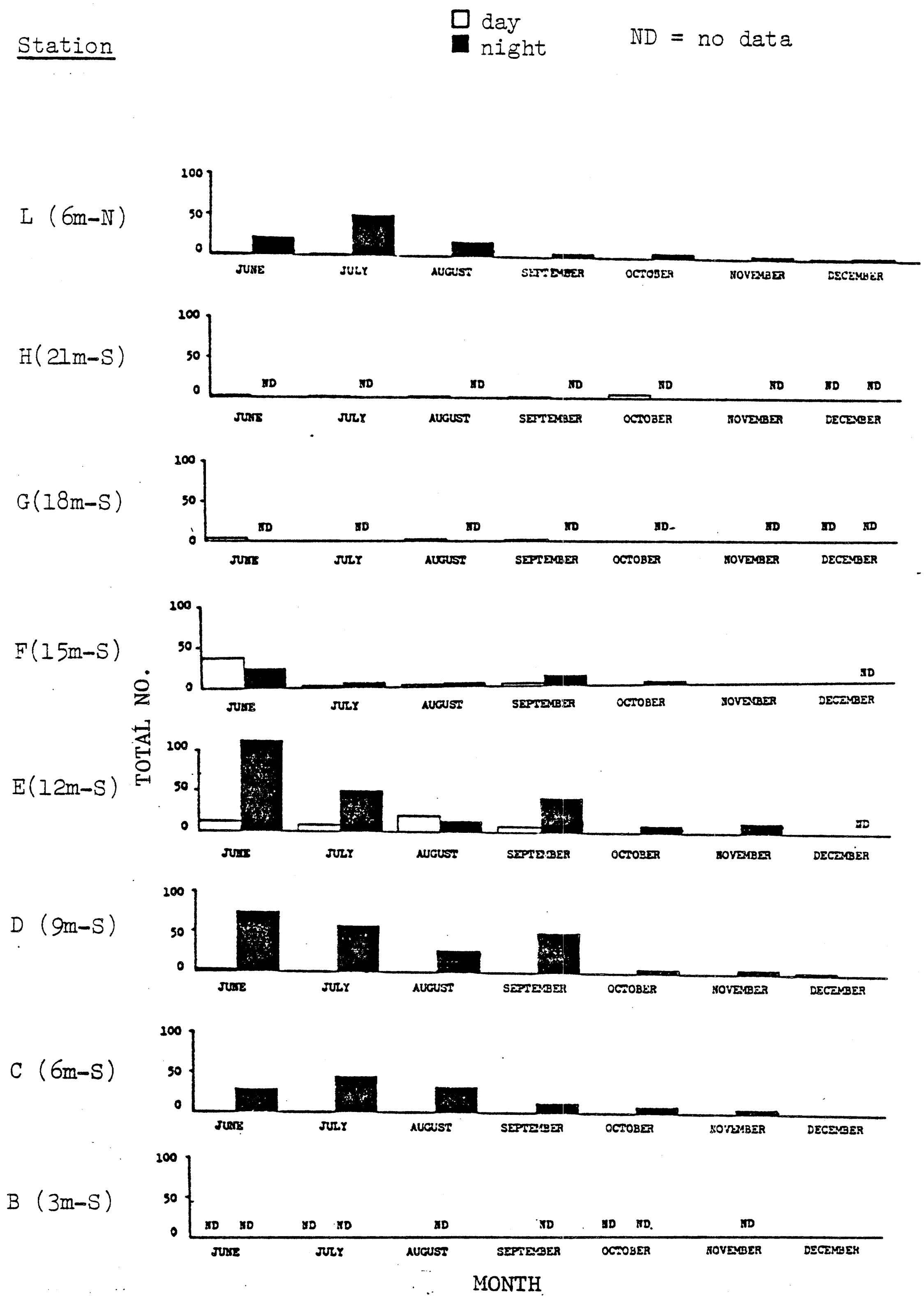


FIG. 59. Total number of trout-perch caught in bottom trawls fished during day and night once per month June through December 1977 in eastern Lake Michigan in the vicinity of the J. H. Campbell Power Plant.

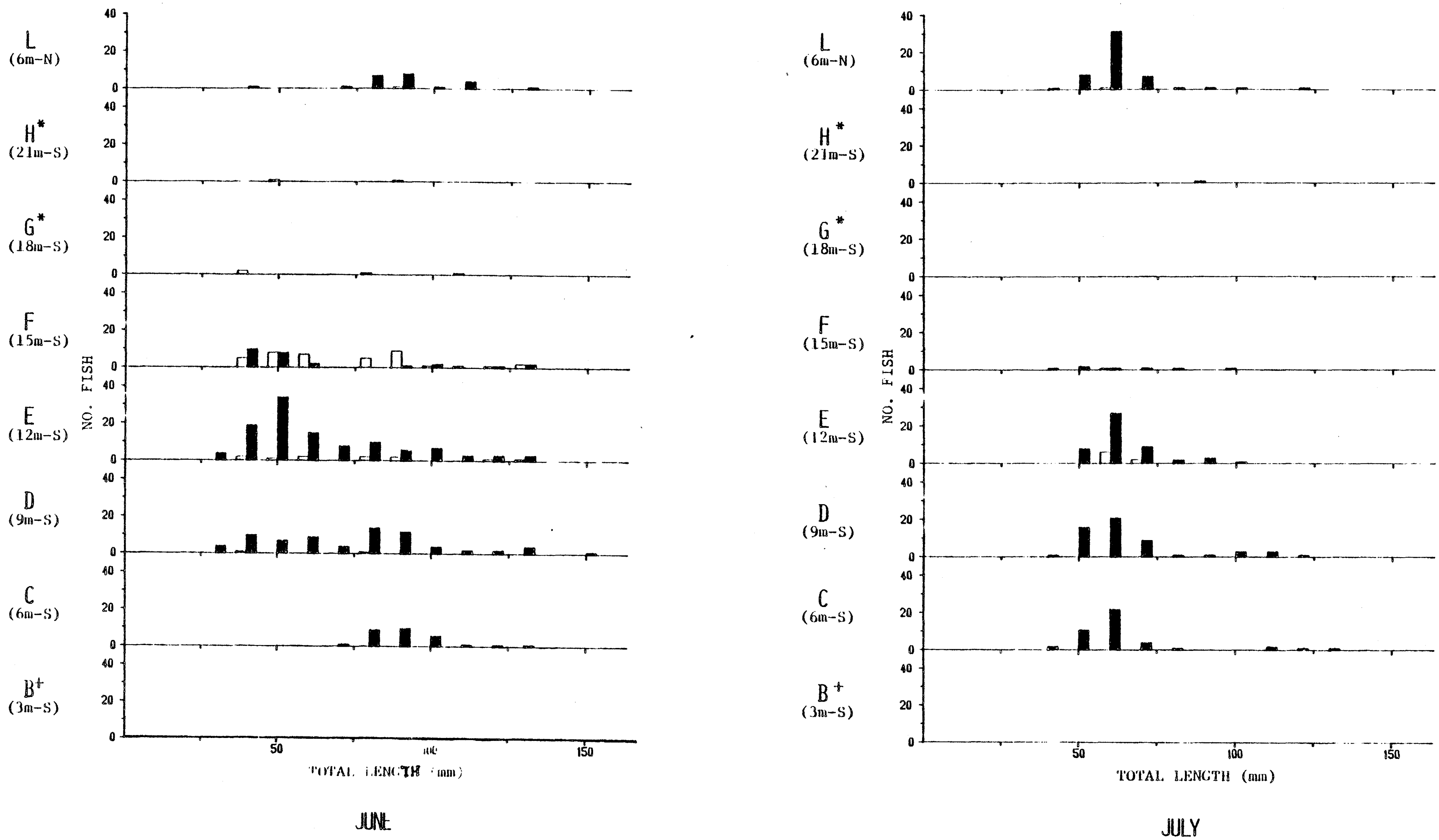
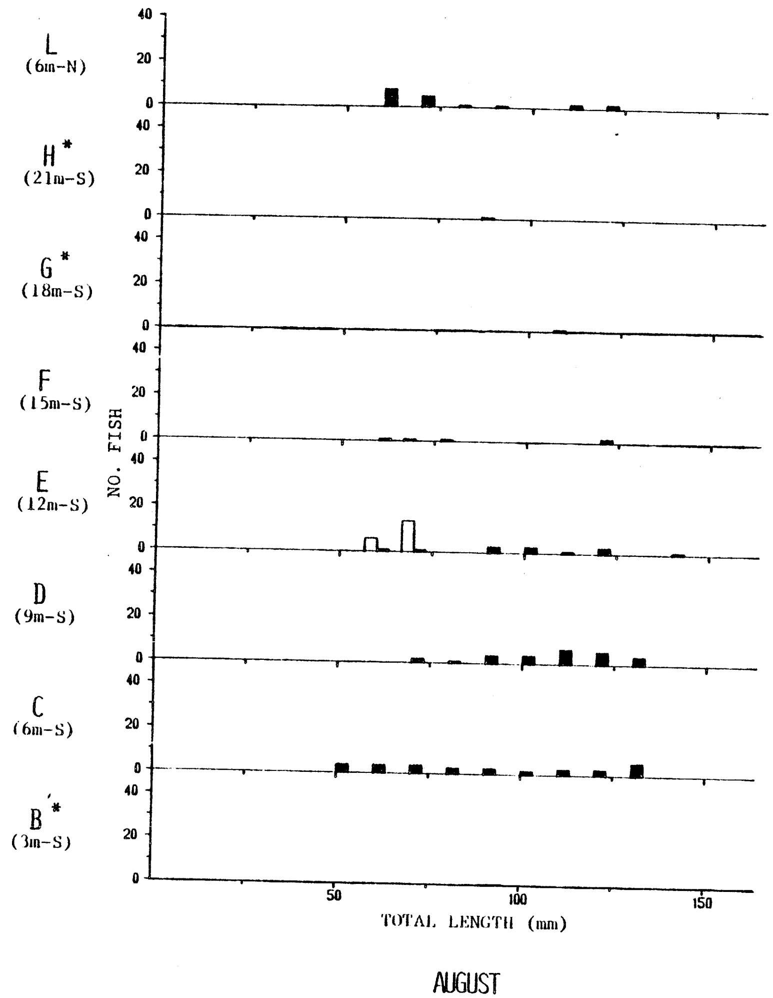


FIG. 60. Length-frequency histograms for trout-perch caught in duplicate trawl hauls during June to December 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.

□ = day ■ = night.

* = No night sampling performed.

+ = No sampling performed.



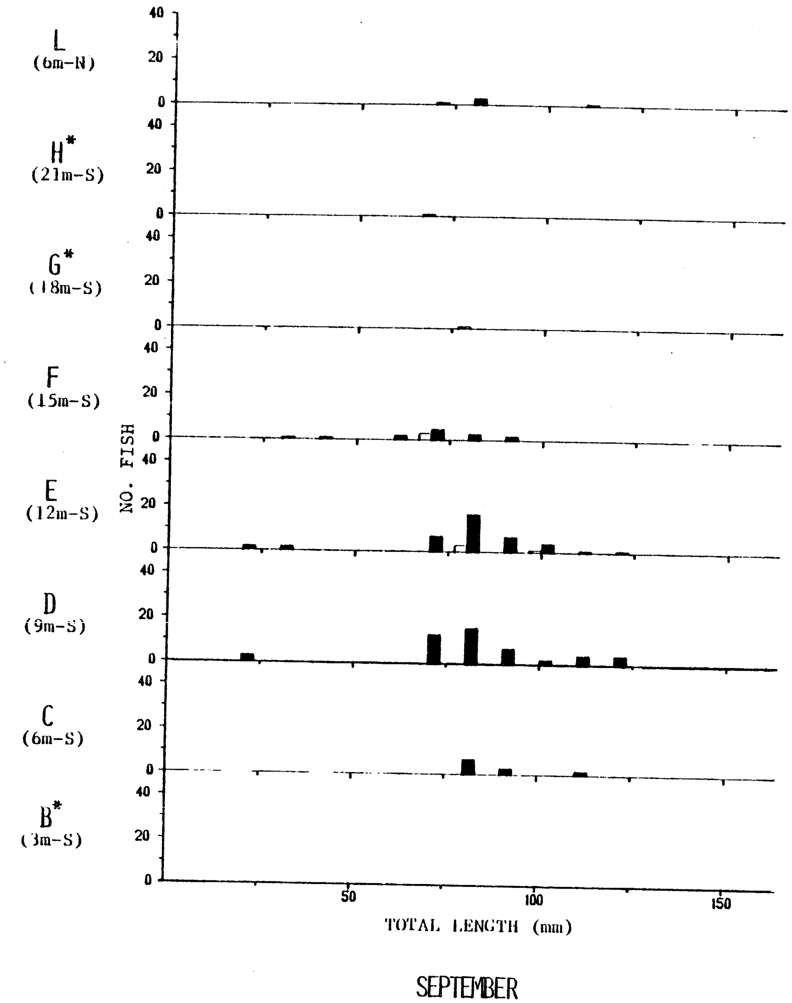
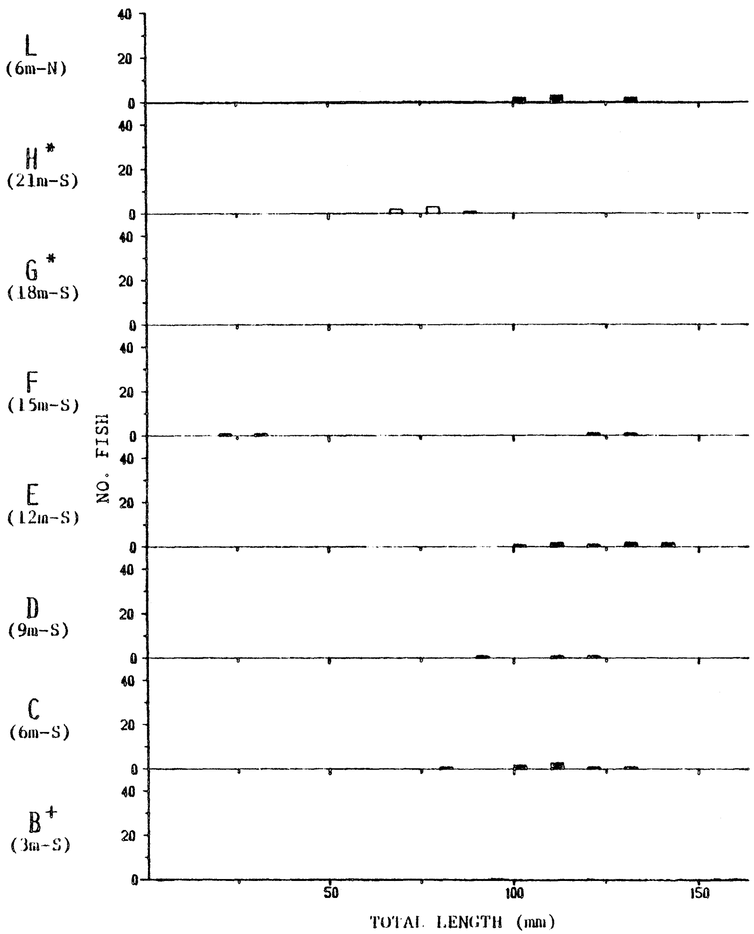
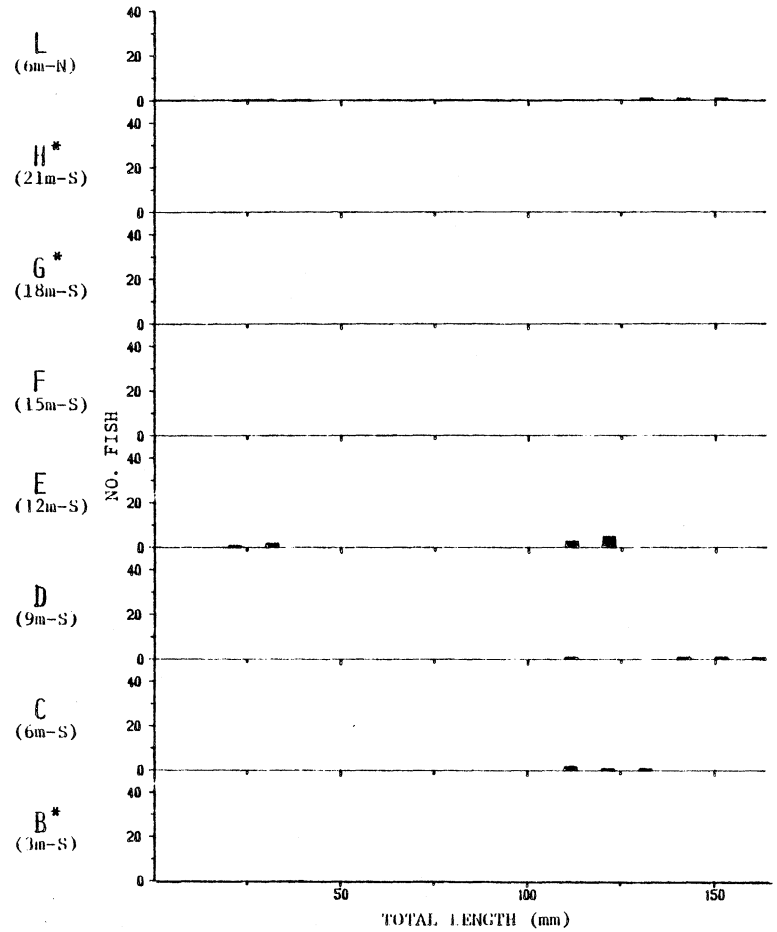


FIG. 60. (Continued)



OCTOBER



NOVEMBER

FIG. 60. (Continued)

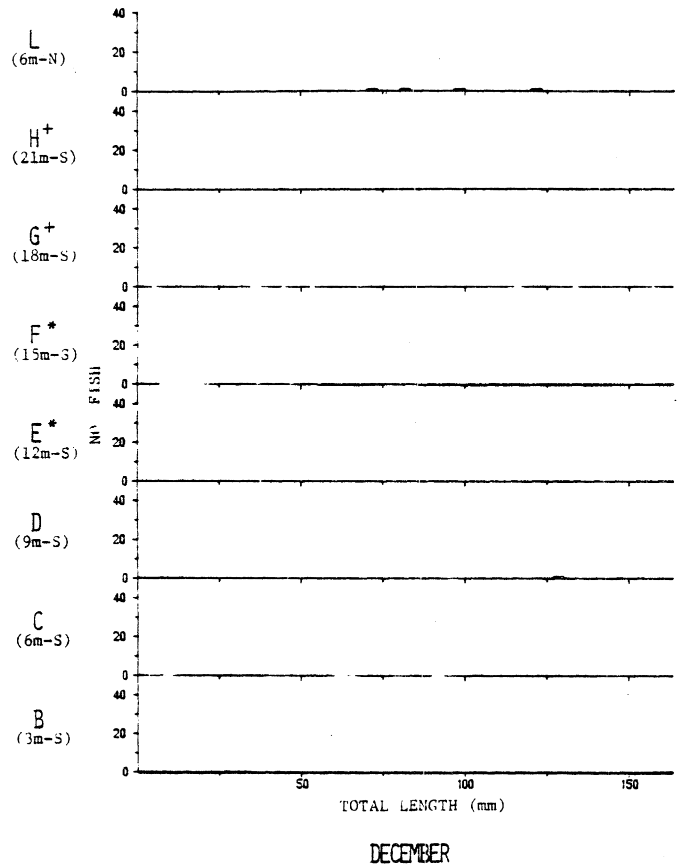


FIG. 60. (Continued)

1973). Near the Campbell Plant, trout-perch probably spawned mostly from June through August (Table 31). Occurrence of trout-perch larvae (see FISH LARVAE AND ENTRAINMENT) and spent adults in Lake Michigan from mid-June to September indicated that trout-perch spawned over a prolonged period.

Nocturnal activity of trout-perch is related to feeding. Scott and Crossman (1973) and Emery (1973) pointed out that trout-perch move toward shallow areas to feed at night and then return to deeper water during the day. Most trout-perch caught in our study area had food in their stomachs.

Trout-perch caught in June ranged from 25 to 150 mm in total length (Appendix 4). Yearlings which included fish from 25 to approximately 74 mm made up about 50% of the 326 trout-perch in the June catch. During the inshore migration these smaller individuals did not seem to come as close to shore as larger ones (Fig. 60). No trout-perch under 75 mm in length were caught in 6 m or shallower water. This size group of fish was distributed in the 9-15 m depth zone, with the largest concentration at 12 m at night; during the day they moved to the 15 m contour. As these yearlings were mostly immature, our data seemed to agree with the

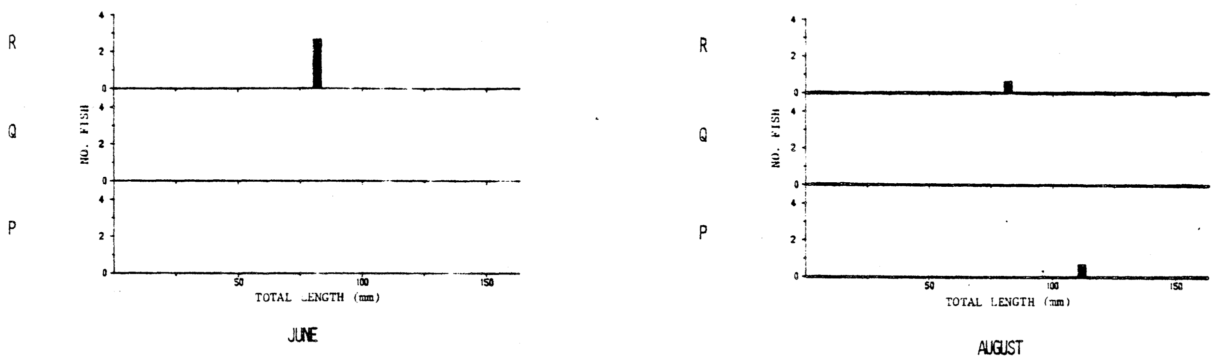


FIG. 61. Length-frequency histograms for trout-perch caught in duplicate seine hauls during June to August 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan. □ = day ■ = night.

observations of Magnuson and Smith (1963) who pointed out that immature age I trout-perch tended to remain in deeper water than mature individuals. Larger trout-perch were distributed from the beach zone to the 12 m depth at night with the majority of fish seeming to move to the 15 m contour during the day (Fig. 60).

July -- In July most trout-perch were caught by trawl. Only a few were taken by gill net (Fig. 62). Most larger trout-perch (over 90 mm in total length) were found at night at 6 to 12 m (Fig. 60). Two large individuals came into shallow water and were caught by a night bottom gill net at 3 m (Fig. 63); but they did not seem to enter the beach zone as none were taken by seine. During the day these large individuals probably returned to 15 m or deeper stations since a few specimens were caught during day trawling (Fig. 60).

Yearling trout-perch 90 mm or less were distributed between 6 and 15 m (Fig. 60). Only a few of these smaller individuals, however, were caught at 15 m where they were commonly found in June both during the day and at night. During July at night the majority of yearling trout-perch occurred at 6 to 12 m (Fig. 60). Yearlings moved closer to shore in July than they did in June and occupied the 6 m contour which was vacated by larger trout-perch. Yearlings did not seem to enter the beach area as none were caught by seine (Appendix 5). These data were in agreement with Jude et al. (1975) who found no yearling trout-perch in seine catches during the summer. During the day yearlings probably moved to 12 or 15 m where a small number of fish were caught in day trawls.

July trout-perch catch decreased substantially from June levels (Appendix 4). The number of yearlings caught showed little change, but there was a marked decline in the number of the larger individuals taken (Fig. 60). The larger trout-perch may have left the study area for warmer waters since water temperatures were between 6.2-7.2 C on the day we sampled. Although July was normally the period of fairly high spawning activity of trout-perch (Jude et al. 1975; Magnuson and Smith 1963), our gonad data (Table 31) indicated that very few trout-perch

TABLE 31. Monthly gonad conditions of trout-perch caught in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development	18	25	10	23	4	1	1
	Mod. development	36	11	17	10	11	8	
	Well developed	19	3	13	6		9	1
	Ripe-running							
	Spent			2	4			
Females	Slight development	15	4	16	30	6		1
	Mod. development	32	5	16	5	13	1	
	Well developed	11	4	8			21	1
	Ripe-running	3		4				
	Spent	3	2	8	3			
	Absorbing							
Immature		113	102	7	10	2	3	1
Unable to distinguish		1	15	7	10			

spawned in July probably because of the low water temperature.

August -- In August, the majority of large and small trout-perch were caught at night between 6 and 12 m (Fig. 60). Several specimens over 90 mm in length were caught in night bottom gill nets at 9, 6 and 3 m (Fig. 63) and two adults were collected by night seine (Fig. 61), indicating that large trout-perch once again were distributed in the beach zone. During the day most trout-perch probably returned to 12 m or deeper water. Several specimens were trawled during the day at 12 m and a few at the deeper stations.

Although the total August trout-perch catch was lower than that of July, larger individuals, approximately 90-137 mm, were slightly more abundant than in July (Appendix 4, Fig. 60). Spawning activity also appeared to increase slightly, as more adults with ripe and spent gonads were found in August than during the previous month (Table 31). The low August catch was due exclusively to the decreased capture of trout-perch 90 mm or less. These smaller individuals must have left the study area.

September -- Migration of trout-perch to deeper water starts in September in southeastern Lake Michigan (Jude et al. 1975) and in late September or early October in Lake Superior (Bostock 1967). A

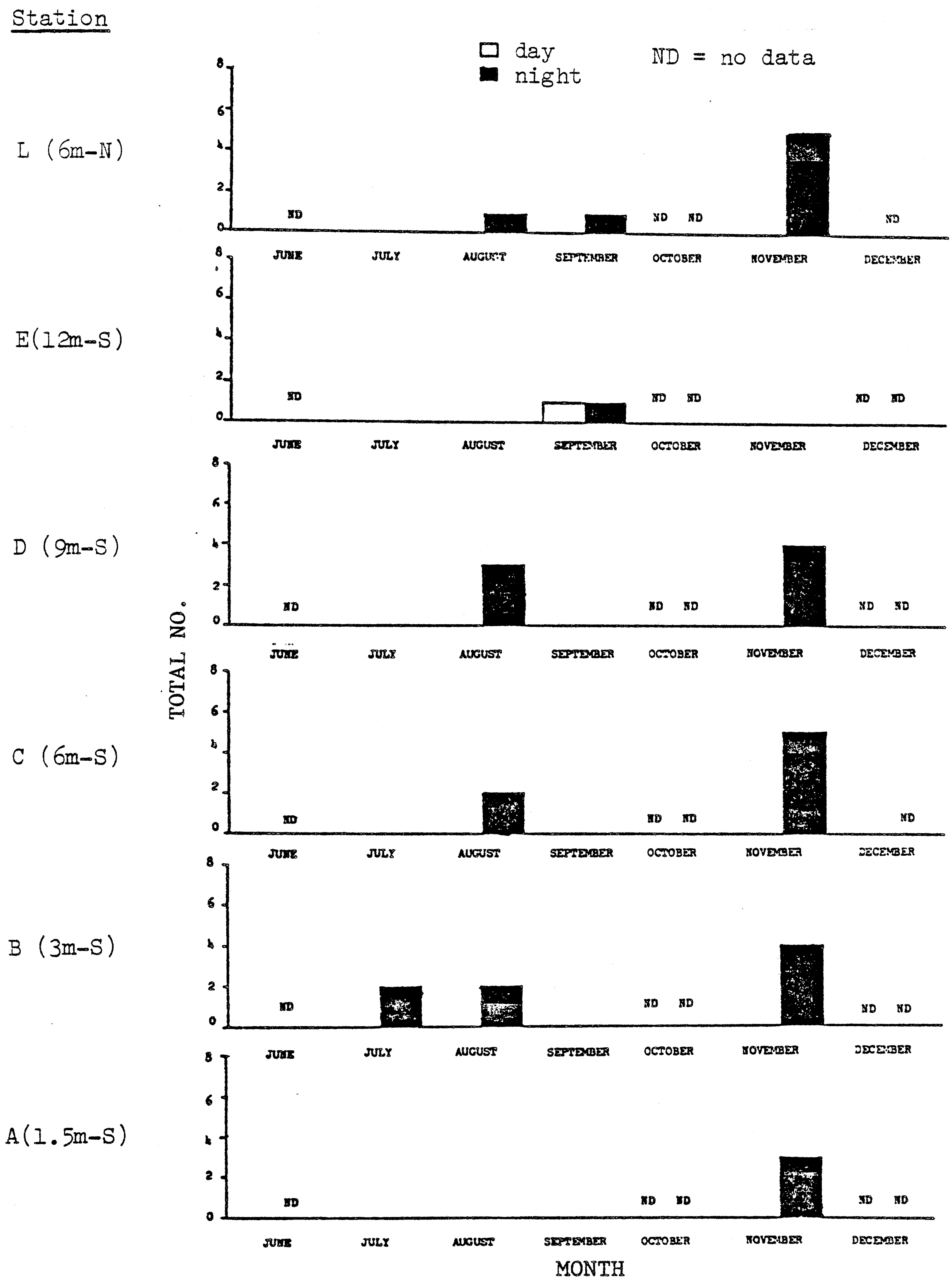


FIG. 62. Total number of trout-perch caught in bottom gill nets fished during day and night once per month June through December 1977 in eastern Lake Michigan in the vicinity of the J. H. Campbell Power Plant.

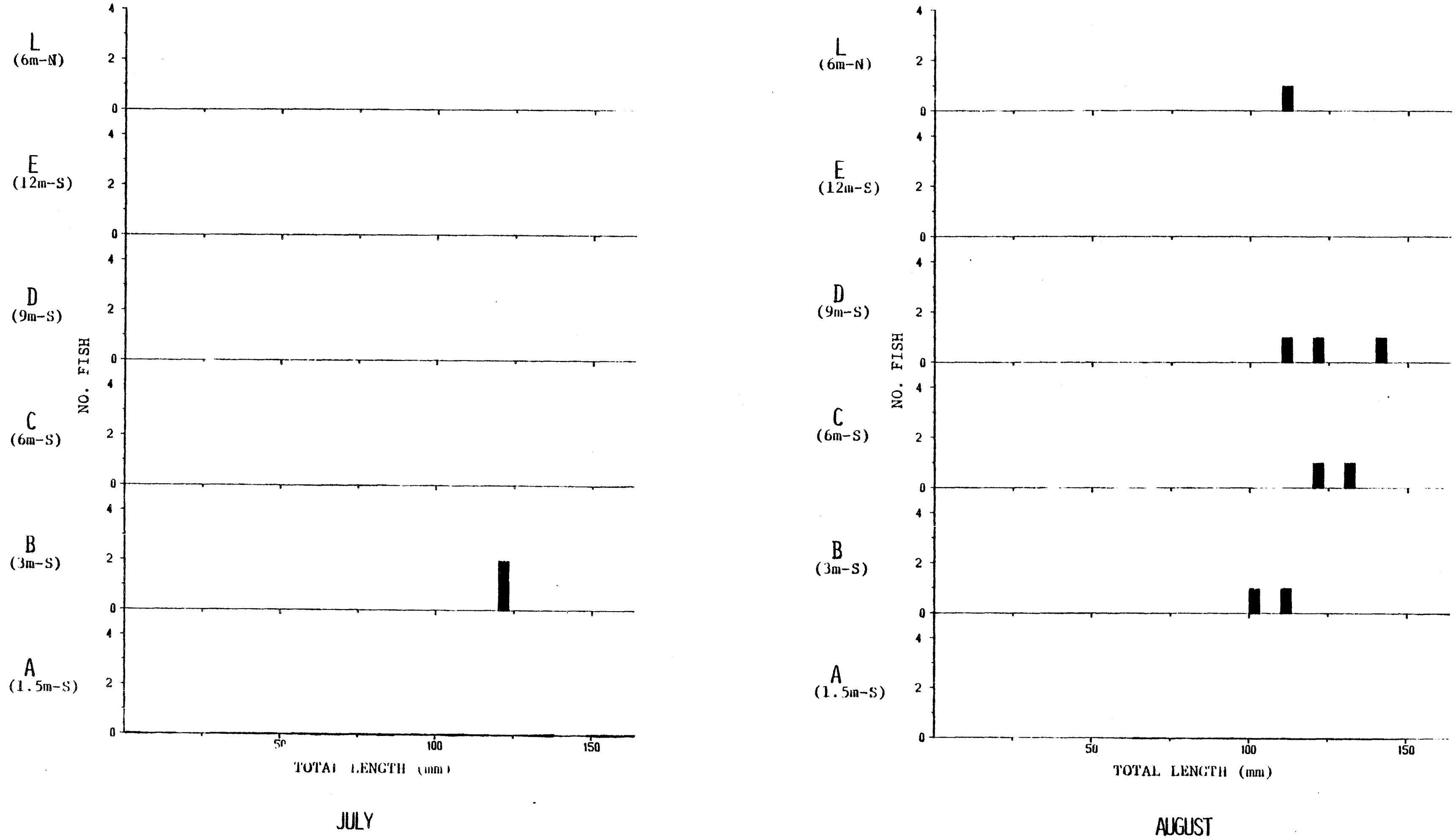
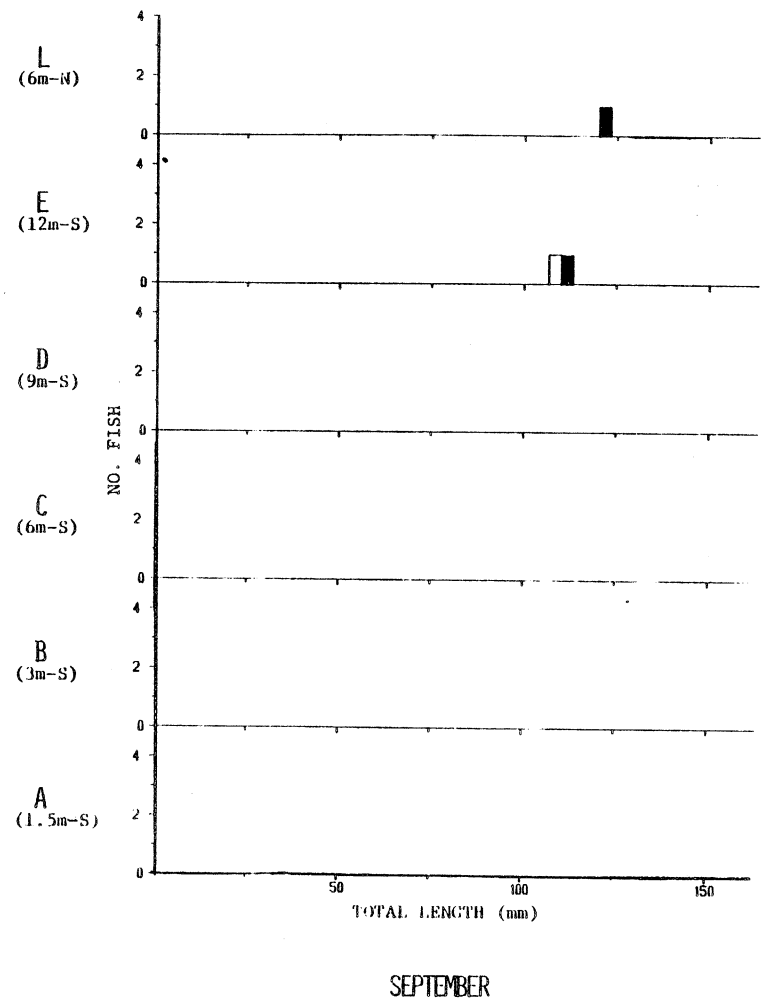


FIG. 63. Length-frequency histograms for trout-perch caught in duplicate bottom gill nets during July to November 1977 in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.



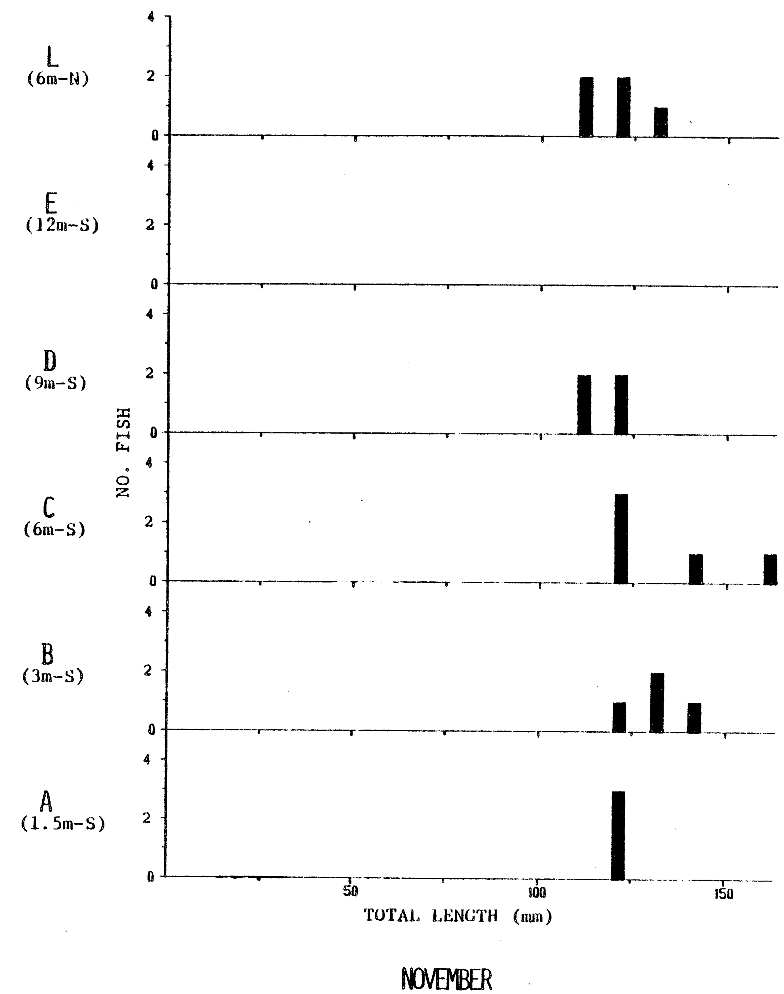


FIG. 63. (Continued)

relatively large number of trout-perch were trawled in the 6-15 m zone in September in our study area (Fig. 60) indicating that they still remained inshore. No trout-perch were caught inside the 6 m contour. A few specimens were taken by gill net at 6 and 12 m (Fig. 63), but none were seined. The number of yearling trout-perch of approximately 90 mm or less had increased slightly in our catch compared to August collections (Fig. 60).

YOY measuring 20-40 mm first entered the trawl catch in September (Fig. 60). In the vicinity of the D. C. Cook Plant, southeastern Lake Michigan, YOY trout-perch of comparable size also were caught in September (Jude et al. 1975). During the previous months these YOY were probably too small to be caught in the sampling gear. YOY apparently exhibited the same nocturnal behavior as the larger fish as they were caught only at night. Of course net avoidance is also a factor.

October -- Trout-perch catch declined sharply in October at every depth sampled, indicating that most fish had already left for deeper water. Several individuals over 90 mm were still caught by trawl between 6-12 m, but yearlings had almost completely disappeared from inshore water (Fig. 60). Due to bad weather no gill nets were set this month and no trout-perch were caught by seine. YOY, ranging from 25 to 35 mm apparently also started their offshore migration at this time, since they were found in deeper water than in September (Fig. 60).

November and December -- No trout-perch were caught by seine in November. Several large individuals, however, occurred in the night trawl catches from 6-12 m (Fig. 60) and in night gill net catches from 1.5-9 m (Fig. 63). The relatively warm water (10.9-12.9 C) in November may have delayed their retreat to deeper water. No yearlings were found inshore in November. A few YOY, 25-30 mm, were also included in the November trawl catch (Fig. 60). By December, practically all trout-perch had left the inshore region. Only a few large individuals were caught by trawl at 6 m (Fig. 60). No trout-perch were caught in surface gill nets during the study period corroborating that they are benthic species.

<u>Temperature-Catch Relationships</u> -- Catch temperatures for trout-perch ranged from 1 to 21.5 C. The majority of specimens were collected between 6 and 12 C. In southeastern Lake Michigan trout-perch tended to occur in slightly higher temperature ranges. They were mostly found at 10-15 C off Saugatuck, Michigan (Wells 1968) and between 14-20 C near the D. C. Cook Plant, southeastern Lake Michigan (Jude et al. 1975). Trout-perch probably remained active at lower temperatures. Most specimens collected in water as cold as 1 C had food in their stomachs.

Although there appeared to be no statistically significant correlation between sizes of trout-perch and the water temperatures at which they were caught, fish larger than 90 mm tended to be found in slightly warmer water than smaller fish (Fig. 64). This difference in temperature preference between sizes of trout-perch may be an important factor influencing the distribution of various sizes of trout-perch in our study area. Trout-perch 90 mm or less were commonly found on 27 July when water temperatures ranged mostly from 5.3 to 7.2 C (Fig. 60). The catch decline observed on 15 August (Fig. 60) coincided with higher temperatures which ranged mostly from 15 to 21.5 C. The slight catch increase of trout-perch on 21 September corresponded to a drop in temperature to 5.1-7.3 C. Decline of the catch of trout-perch over 90 mm on 27 July (Fig. 60) and its increase on 15 August also coincided with the low and high water temperatures mentioned above.

Decrease in the number of large trout-perch caught in July may in part result from the movement of ripe adults to a more favorable water temperature. Trout-perch generally spawn in relatively warm water. Spawning took place at water temperatures of 16-20 C in Lake Winnebago (Carlander 1969) and 19-21.4 C in western Lake Erie (Kinney 1950). Magnuson and Smith (1963) reported that the peak spawning run in Lower Red Lake occurred after the mean air temperature had remained over 10 C for 44 days. In Heming Lake, Manitoba trout-perch spawned at a slightly lower temperature range (6-11 C) (Lawler 1954).

Only four trout-perch were caught in Pigeon Lake, all by bottom gill net at station M (influenced by Lake Michigan); two were caught in November and two in December (Appendix 4). This species, however, may enter Pigeon Lake more frequently than our catch suggested. During the period January 1974-March 1975, 174 specimens were found in impingement samples from the Campbell Plant (Consumers Power Company 1975). Water temperatures may have influenced movements of trout-perch into Pigeon Lake during colder months. In December, water temperature was 1 C in the inshore area of Lake Michigan and 2.4 C at station M (influenced by Lake Michigan). Most trout-perch, however, seemed to enter Pigeon Lake during the fall. Of the 174 fish found in the 1975 impingement samples, 61 were collected in October and 63 in November. Although trout-perch were known to spawn in tributary water (Lawler 1954; Scott and Crossman 1973), 1977 data showed no evidence that spawning took place in Pigeon Lake.

Other Considerations -- Mortality of trout-perch following spawning reported by Kinney (1950) and Magnuson and Smith (1963) has not been observed in southeastern Lake Michigan (Jude et al. 1975) or in our study area.

Growth rates of trout-perch reported in the literature varied considerably in different bodies of water. At the end of their first

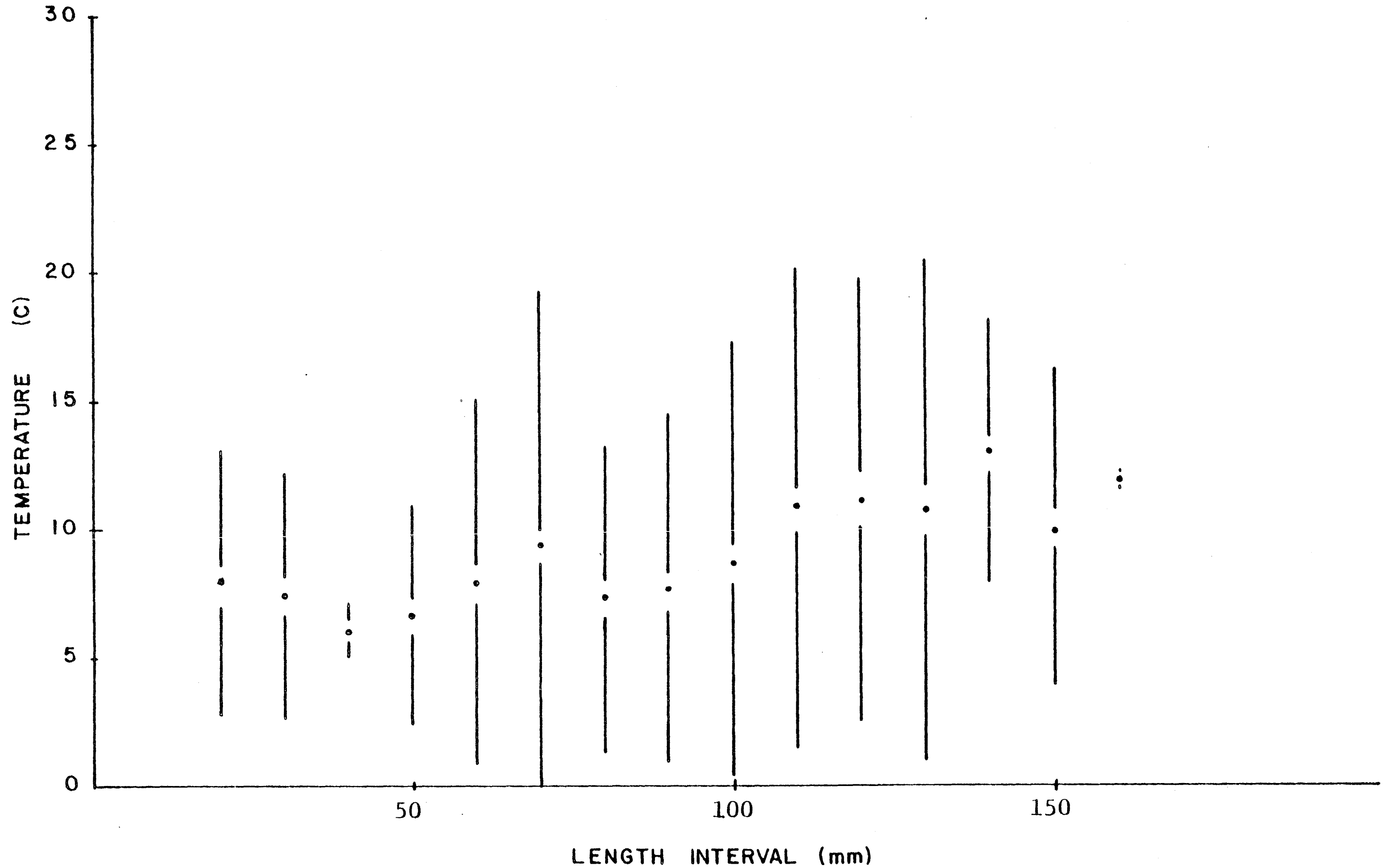


FIG. 64. Weighted-mean temperatures for 10 mm length intervals of trout-perch caught by all gear types from Lake Michigan in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1977. Vertical lines represent ± 2 standard deviations.

year of life, trout-perch grew to 65-92.5 mm in total length for both sexes in Lake Erie (Kinney 1950), 30.1 and 38.1 mm for male and female respectively in Lake Superior (Bostock 1967) and 51.4 and 50.8 mm for male and female respectively in Lower Red Lake (Magnuson and Smith 1963). Trout-perch in Lake Michigan seemed to have slower growth than those of Lake Erie and Lower Red Lake, but considerably faster growth than Lake Superior trout-perch. The calculated length of trout-perch at the end of the first year of life in southeastern Lake Michigan was 49 mm (House and Wells 1975). The age I trout-perch collected in June in the study area ranged in size from 25 to approximately 74 mm and had a modal length of 50 mm (Appendix 4). Near the D. C. Cook Plant, southeastern Lake Michigan, age I trout-perch appeared to grow slightly slower than our yearlings, reaching a modal length of only 45 mm in May and June and 50 mm in July (Jude et al. 1975). Length-frequency data (Appendix 4) suggested that age I trout-perch reached estimated modal lengths of 60, 70 and 80 mm respectively for July, August and September. Although these data (Appendix 4) showed no length increase by trout-perch in October, growth may continue at a slower rate. House and Wells (1973) reported that at Saugatuck, Michigan, all trout-perch appeared to have completed more than 80%, but less than 100%, of the total growth of the year by October.

Although trout-perch were considered an important food of predatory fishes in several lakes, they apparently played a minor role as forage species in Lake Michigan. They seldom occurred in the stomachs of piscivorous fishes like yellow perch, northern pike, lake, brown and rainbow trout, chinook and coho salmon (Jude et al. 1975). Alewives which were abundant in our study area appeared to be preferred food for larger predatory fishes. Stomachs of lake trout caught in the study area contained mostly alewives and no trout-perch. Abundance of trout-perch in southeastern Lake Michigan was believed to result from lack of predation (Jude et al. 1975).

Trout-perch appeared to be homogenously distributed in the study area. There was no difference between catches at station C (6 m - reference) and station L (6 m - s. discharge) during the study period (see STATISTICS).

<u>Summary</u> -- Trout-perch were caught mostly in Lake Michigan. Only a few specimens were collected in Pigeon Lake. They remain in deep water in winter and migrate inshore in spring and summer. In the study area, spawning probably occurred in the shallow water of Lake Michigan from June through August. Although trout-perch were known to spawn in tributary waters our data showed no evidence that spawning took place in Pigeon Lake.

A small number of YOY measuring 20-40 mm first appeared in the September trawl catches in water ranging from 9 to 15 m. Prior to this

month YOY were probably too small to be retained in our fishing gear. A few YOY were again caught in October and November. YOY probably retreated to deeper water in winter.

Yearling trout-perch generally occurred between 6 and 15 m. More were caught in June and July than in August and September. They probably moved offshore in October as no yearlings were caught in this month or the rest of the year.

Adult trout-perch were caught between 6 and 15 m. Highest catches of adult trout-perch were made in June. A modest adult population appeared to remain in the study area during the summer. Offshore migration generally started in the fall. Several large trout-perch, however, still occurred in October and November catches.

The majority of trout-perch were caught between 6 and 12 C. In the summer yearlings tended to be found in slightly cooler water than adults. More trout-perch of all sizes were caught at night than during the day.

Largemouth Bass --

Introduction -- In North America the native range of the largemouth bass extends from southern Ontario and Quebec throughout the Great Lakes and the Mississippi Valley south to Florida and northeastern Mexico (Mraz et al. 1971). Highly regarded as a sport fish, the largemouth bass is often stocked in farm ponds. Such introductions have extended the range of this species westward. Largemouth bass are widely distributed within the Great Lakes basin inhabiting shallow, weedy lakes and river backwashes (Mraz et al. 1971) usually at depths less than 6 m (Becker 1976).

Largemouth bass fry selectively feed on limnetic copepods and cladocerans (Elliott 1976). Immature and mature largemouth bass consume aquatic insects, fish (Bennett and Gibbons 1972), crayfish and frogs (Mraz et al. 1971), seasonally dependent upon the size and availability of food. In the field, largemouth bass preferred water temperatures between 26.6 and 27.7 C (Scott and Crossmann 1973). However, Becker (1976) states that the species is most active between 15.6 and 24.4 C. Spawning occurs from late spring to mid-summer, with a peak noted in early to mid-June (Scott and Crossman 1973). Nesting sites, usually in sand and gravel, are prepared by the male when water temperatures reach 15.6 C and egg laying follows after temperatures reach 16.7 to 18.3 C (Mraz et al. 1971). During the 3 to 7 days it takes for eggs to hatch, the male guards the nest aggressively. Sexual maturity is achieved in 3 to 5 yrs (Scott and Crossman 1973) at which time the fish reach lengths of approximately 300 mm.

Seasonal Distribution -- All largemouth bass caught in the Campbell Plant area were from Pigeon Lake; they were collected from all stations except openwater station M (influenced by Lake Michigan). Station M differs from the others primarily because it is deeper and offers less macrophyte cover than other sampling areas. Consequently, absence of largemouths at this station could be due to its physical characteristics. Nearly twice as many largemouth bass were captured during the day (495) as during the night (265) (Appendix 4). Of the total catch, 99% were caught in seines and nearly all were YOY (Appendix 5).

The largest monthly seine catch (273) occurred in June (Fig. 65). All fish were YOY, except four which included three yearlings (90-110 mm) caught at station V (undisturbed Pigeon Lake) and one adult (370 mm) caught at station T (influenced by Pigeon River). Mean length of YOY during June was 23 mm (range 17-31 mm). Nearly all YOY were caught at station T with considerably more caught during the day (209) than at night (58) (Fig. 66). The three yearlings and one YOY were caught at station V and two YOY were caught at station S.

Observed abundance patterns of bass larvae and subsequent YOY were similar. Highest concentrations of larvae caught in plankton nets and YOY caught in seines both occurred at station T. Apparently the dispersion rates of early life stages of largemouth bass were low during summer months. The one adult captured at station T was a spent female indicating that some spawning occurred prior to 3 June (Table 32).

Most largemouths caught in July were YOY (Appendix 5). Only three larger bass (range 115-167 mm) were taken and these were caught at beach stations S (influenced by Lake Michigan) and V (undisturbed Pigeon Lake). More YOY were caught at stations V and S in July than in June. In addition far more YOY bass were caught at station T in July than were caught at the other two beach stations. Numbers of bass caught at station T decreased in July when compared with June. Rapid growth of YOY bass occurred between June and July as mean length increased from 23 mm to 57 mm, over a doubling in length. Length range of bass in July was 29-85 mm. Day catches were approximately equal to night catches.

Growth of YOY continued in August, but length did not increase as rapidly. Total catch continued to decrease (Appendix 4) when compared to previous months. Larger numbers of bass were caught at beach stations V and S than in previous months, but YOY remained concentrated at station T (Fig. 66). Two older fish (148 and 170 mm) were caught at station V. Length range of YOY caught in August was 38-109 mm (mean length = 67 mm). One YOY and two adults were caught in a day gill net at openwater station Y (Fig. 67).

In September, YOY ranged from 58-113 mm with a mean length of 78 mm (Appendix 4). Most YOY were caught at station T and some at station V

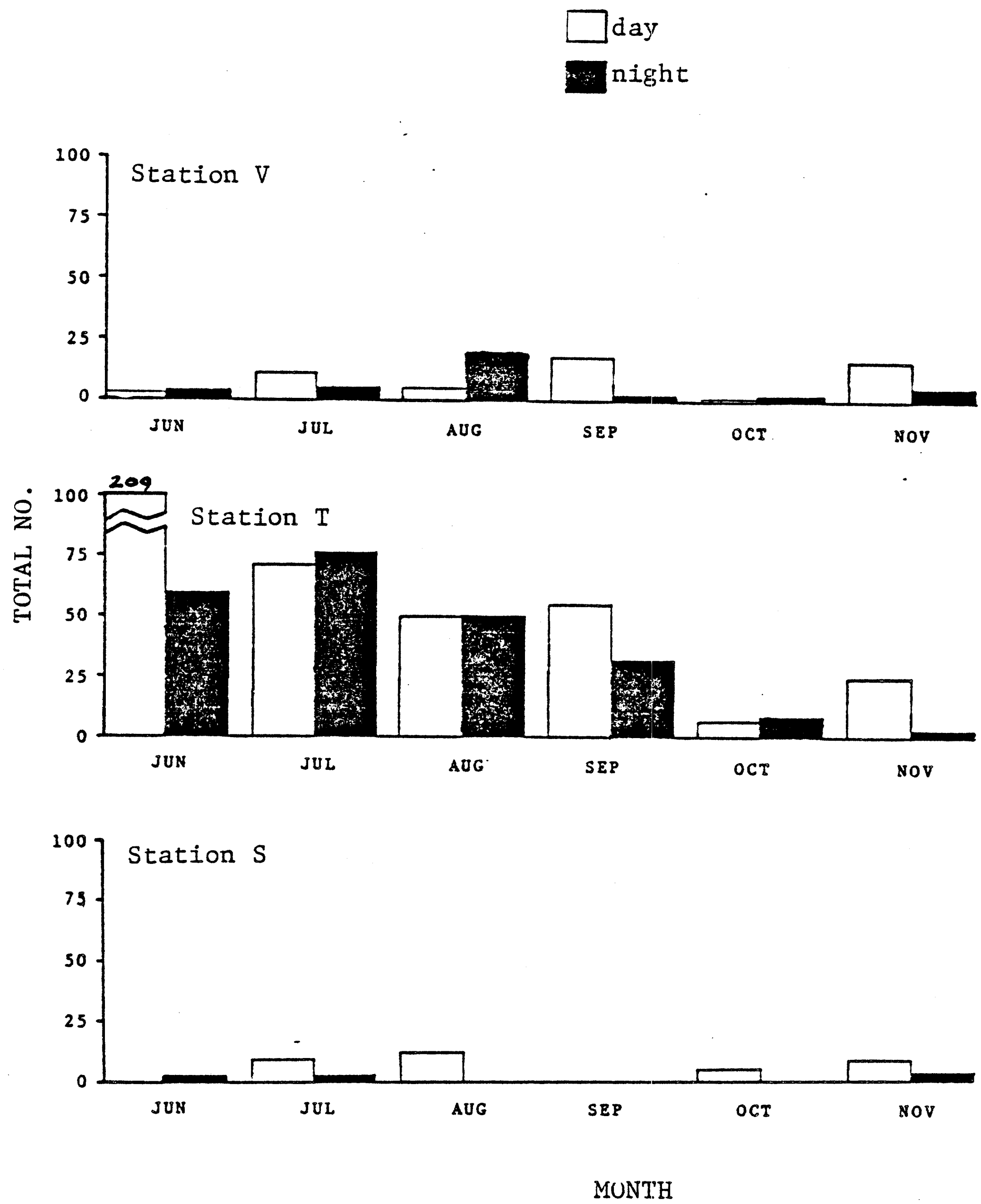


FIG. 65. Total number of largemouth bass caught in duplicate seine hauls in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, June - November 1977.

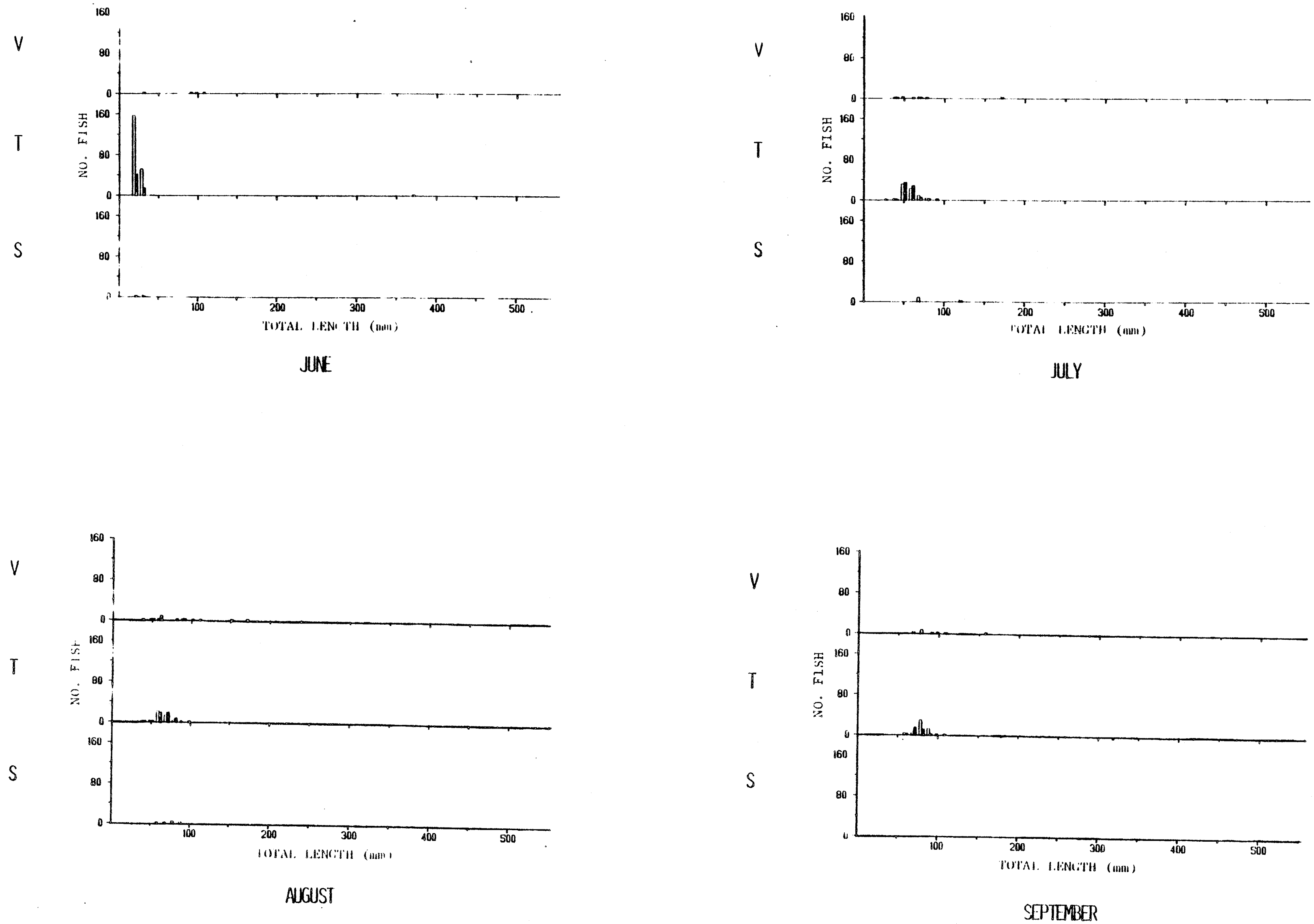


FIG. 66. Length-frequency histograms for largemouth bass caught in duplicate seine hauls during June to November 1977 in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan. □ = day ■ = night.

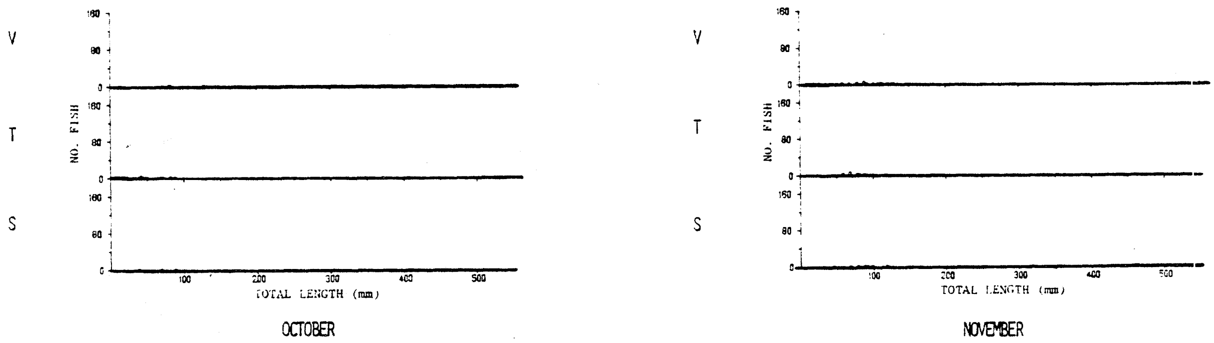


FIG. 66. (Continued)

TABLE 32. Monthly gonad conditions of largemouth bass caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development	2	1	10	14	4	11	
	Mod. Development		1			1	2	
	Well developed							
	Ripe-running							
	Spent							
Females	Slight development		2	8	2	1	7	
	Mod. development				1			
	Well developed							
	Ripe-running							
	Spent	1						
	Absorbing							
Immature		36	93	78	40	10	20	
Unable to distinguish					10		1	

(Fig. 66). Three adults were caught in a gill net at station Y (Fig. 67).

Catches of bass in October were the lowest of the study period (Appendix 4), but increased again in November. Mean lengths of largemouth bass YOY in October and November were 73 and 77 mm, respectively. Catch of bass at station S remained low. Catches at beach stations V and T were similar for these 2 months (Fig. 66).

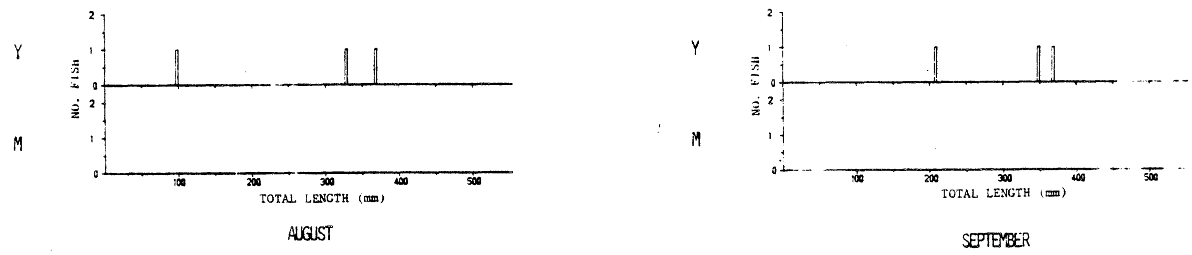


FIG. 67. Length-frequency histograms for largemouth bass caught in duplicate bottom gill nets during August and September 1977 in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.

Length ranges for YOY bass in October and November were 49-126 mm and 57-128 mm, respectively.

Temperature-Catch Relationships -- Temperatures at time of capture are probably not good indicators of thermal preference due to confounding by the seasonal temperature cycle and unavailability of a large range of temperatures. Largemouth bass YOY remained close to shore and probably would not behaviorally thermoregulate like some Lake Michigan species, due to the limited range of available temperatures. Fish 30-50 mm were caught at low water temperatures in June, while weighted-mean temperatures for other YOY bass intervals reflected summer temperatures (Fig. 68).

Other Considerations -- Stomach analyses of YOY largemouth showed that most were eating amphipods which were extremely abundant in the weedy areas of Pigeon Lake. Other prey items included dragonfly nymphs, damselfly adults and corixids (water boatmen). Excellent food supply is clearly responsible for the abundance and good growth of bass in the lake.

Summary -- Largemouth bass in Pigeon Lake probably spawned before 3 June and beach station T served as an important nursery area. Few adults were among the 760 caught. Most were taken during June in seines. Declining YOY catches throughout the year at station T probably were indicative of a decreasing population, as high mortality due to predation, disease and other causes would be expected to occur during this life history stage. No largemouth bass were caught at station M (influenced by Lake Michigan) where there was less macrophyte cover. Growth of YOY bass was very rapid through the summer and may slow in October. Amphipods, which were extremely abundant in weedy areas, were the predominant food of YOY largemouth and along with other abundant food clearly responsible for the abundance and good growth of bass in the lake. Adult largemouth apparently avoided seines and gill nets since few adults were caught at any time of the year, yet many were seen during the mark and recapture study.

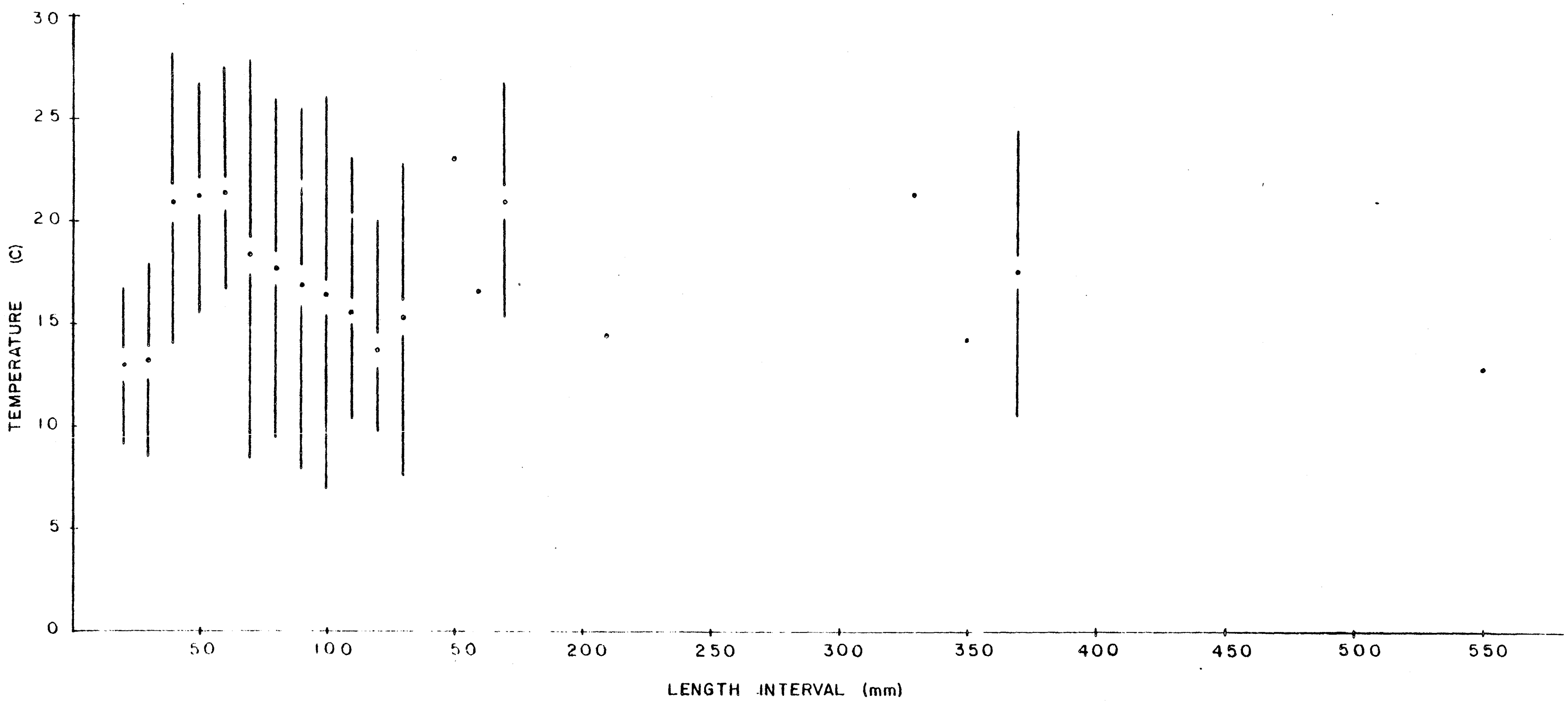


FIG. 68. Weighted-mean temperatures for 10 mm length intervals of largemouth bass caught by all gear types from Pigeon Lake in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1977. Vertical lines represent ± 2 standard deviations.

Pumpkinseed --

Introduction -- The pumpkinseed (Lepomis gibbosus) is restricted to the fresh waters of eastern North America (Scott and Crossman 1973). It prefers weedy areas of lakes, ponds and streams, in cool to moderately warm water (Hubbs and Lagler 1958). In Lake Michigan, it is found in the shallow water of protected bays (Becker 1976).

Pumpkinseed spawn in late spring and summer. Carbine (1942) reported that pumpkinseed spawned from 31 May to 18 July in Deep Lake, Michigan. This species feeds primarily on insects, small molluscs and crustaceans. In addition, larger pumpkinseed may feed on small fish, including their own young (Trautman 1957). Pumpkinseed are valued as a sport fish (although in some overcrowded situations, stunting may occur). The young serve as forage for other game species. They also make attractive aquarium fish due to their colorful markings (Becker 1976).

Seasonal Distribution -- Pumpkinseed were collected from Pigeon Lake (232 individuals) and from Lake Michigan, where one was seined at beach station R (n. discharge) (Appendix 4). Pumpkinseed were the second most abundant centrarchid collected (second only to largemouth bass) and represented 1.1% of the total catch of all species taken from Pigeon Lake (Table 14). Of those collected from Pigeon Lake, 228 were taken with beach seines and four were collected in bottom gill nets (Table 19) set at openwater station Y (influenced by Pigeon River).

Sizes of pumpkinseed caught ranged from 25 to 199 mm, with most (118) found in the 40-60 mm range. According to age-length data from a Michigan pond given by Scott and Crossman (1973) fish we caught would range in age from YOY to age 8.

In June most pumpkinseed were caught at beach station T (influenced by Pigeon River) (Fig. 69). They ranged in size from 40 to 130 mm and were probably all adults.

The first occurrence of YOY pumpkinseed was in July at beach station T. YOY were not caught at other Pigeon Lake beach stations (S and V) at this time. These areas might not be as suitable for the rearing of young as was station T. The large size of YOY (30-50 mm) caught in July (Appendix 5) suggested that spawning had begun in May prior to the beginning of sampling. Gonad data (Table 33) indicated that spawning was occurring in June.

High numbers of YOY pumpkinseed were again found at station T in August. In addition, some adult pumpkinseed appeared in catches at station V (undisturbed Pigeon Lake). The reason for this movement of adults from station T to station V is unknown but it is possible that

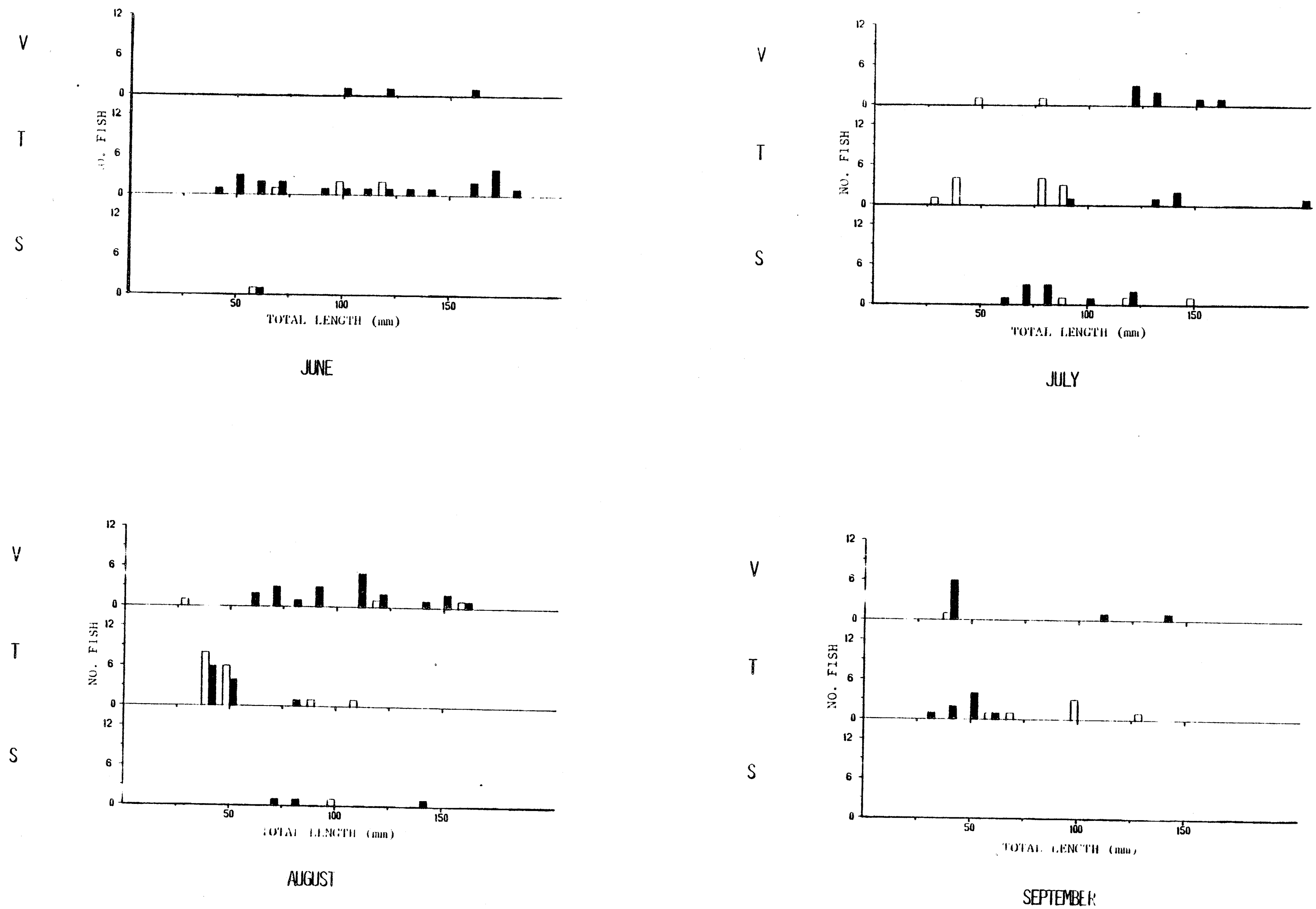


FIG. 69. Length-frequency histograms for pumpkinseed caught in duplicate seine hauls during June to November 1977 in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan.
□ = day ■ = night.

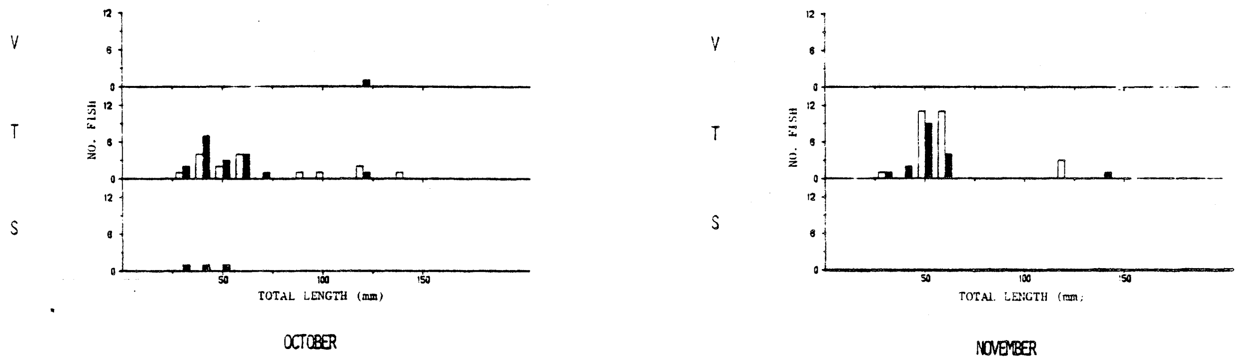


FIG. 69. (Continued)

TABLE 33. Monthly gonad conditions of pumpkinseeds caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development	1	6	13	3	1		
	Mod. development	4	8	2		5	3	
	Well developed	2	1		1			
	Ripe-running							
	Spent							
Females	Slight development	1	1	6	3	1	1	
	Mod development	5	3		2	1	2	
	Well developed	2	9					
	Ripe-running	3						
	Spent			4				
	Absorbing							
Immature		10	6	27	15	30	27	
Unable to distinguish		2	4	1	1			

aquatic vegetation at station T became too thick and discouraged movement of adult fish in the area.

During September there was an apparent movement of adult fish from areas seined. Gill nets set at openwater station Y (influenced by Pigeon River) (Fig. 70) indicated the presence of some adults in deeper water; none were caught there during August. YOY remained in shallow water (Fig. 71).

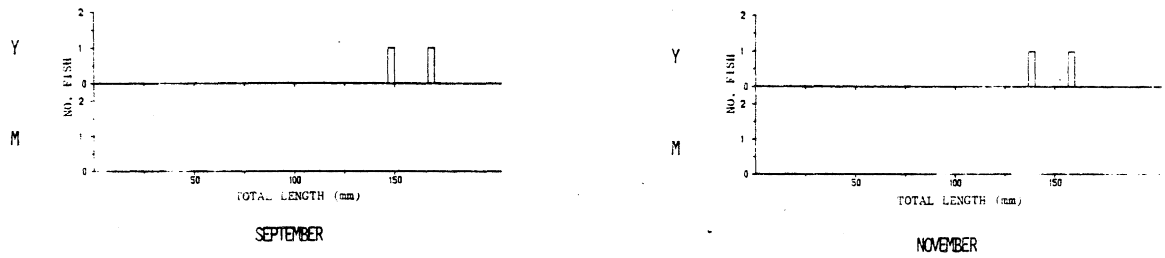


FIG. 70. Length-frequency histograms for pumpkinseed caught in duplicate bottom gill nets during September and November 1977 in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan. □ = day ■ = night.

October seine catches showed a similar trend as was found in September. YOY were still found in shallow areas.

November sampling again indicated that some adults were in deeper water, while YOY still inhabited the beach area. Adult pumpkinseed probably overwinter in the relatively deep water near station Y, while YOY probably overwinter in an area closer to shore than adults.

Temperature-Catch Relationships -- A summary of water temperatures at time of capture for different size pumpkinseed did not indicate any clear relationship between temperature and size of fish (Fig. 72). However, Pigeon Lake, in the vicinity of the Pigeon River, is shallow and probably seldom stratifies, causing a very narrow range of water temperatures to be available to fish.

Other considerations -- Pumpkinseeds preferred the weedy, shallower habitat of the eastern end of Pigeon Lake as opposed to the more open, deeper western end of the lake. No pumpkinseed were collected at 6 m station M (influenced by Lake Michigan).

Only one pumpkinseed larva was collected in Pigeon Lake during the entire sampling period (see FISH LARVAE AND ENTRAINMENT). However, small centrarchid larvae are extremely difficult to identify and many of the *Lepomis* spp. larvae found in Pigeon Lake samples could be pumpkinseed.

Summary -- Pumpkinseed were collected almost exclusively from Pigeon Lake and appeared in catches during every month sampled. They seemed to prefer the weedy, shallow eastern end of the lake near the Pigeon River. As winter approached, adults appeared to move to deeper water, while YOY stayed inshore.

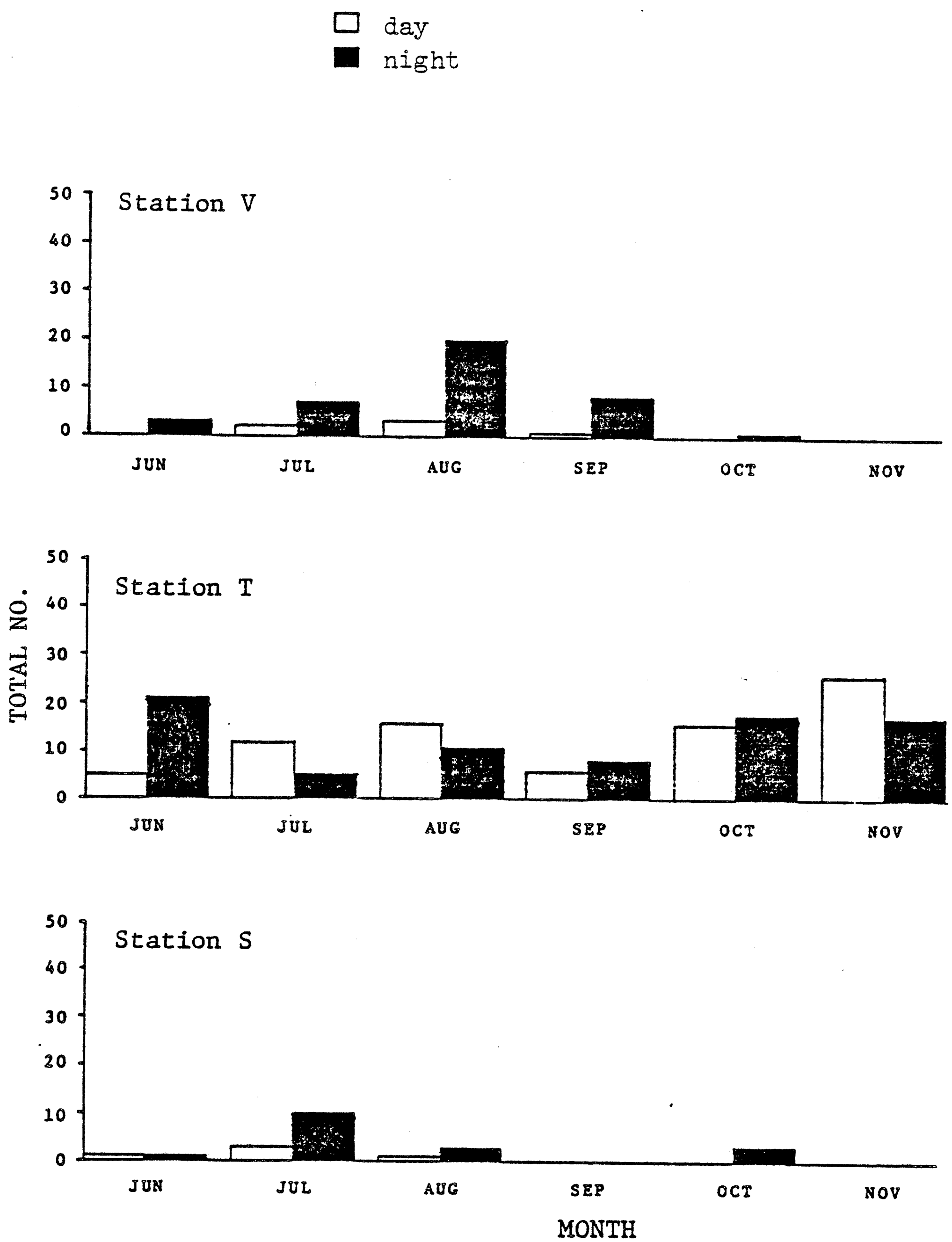


FIG. 71. Total number of pumpkinseed caught in duplicate seine hauls in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, June - November 1977.

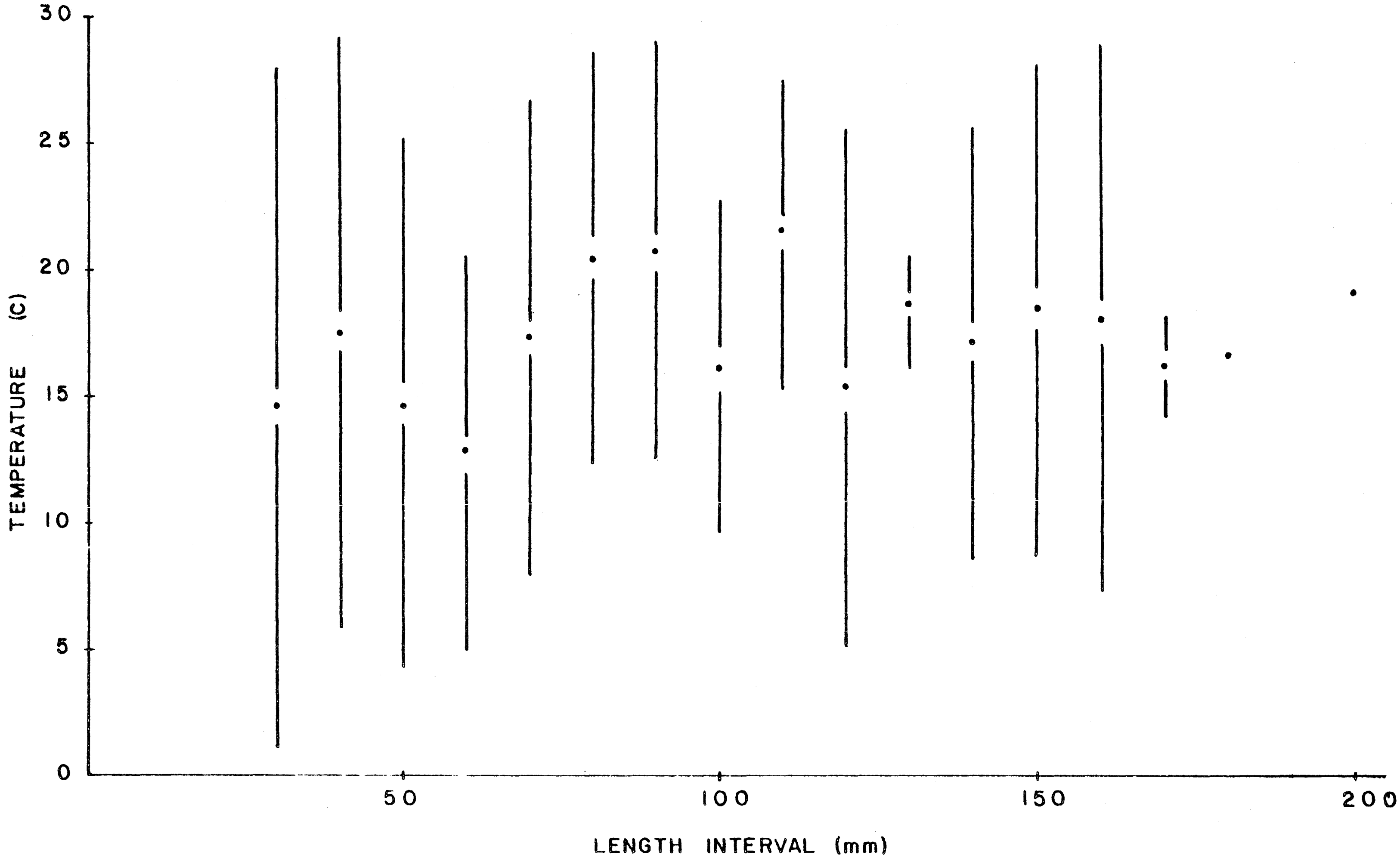


FIG. 72. Weighted-mean temperatures for 10 mm length intervals of pumpkinseeds caught by all gear types from Pigeon Lake in the vicinity of the J. H. Campbell Plant, eastern Lake Michigan, 1977. Vertical lines represent ± 2 standard deviations.

Common Species

Unidentified Coregonids --

Difficulty in identifying species of the genus *Coregonus* (especially individuals under 180 mm) was noted by several authors (Scott and Crossman 1973, Wells and Beeton 1963, Dryer and Beil 1968). These fish vary in shape, size, growth rate, and numbers of scales and gill rakers from lake to lake and introgression between species is believed to occur (Scott and Crossman 1973). At present, keys for separating species of *Coregonus* (subgenus *Leucichthys*) are unsatisfactory.

Historically, a seven species complex of "chubs" (deep water members of the subgenus *Leucichthys*) have populated Lake Michigan. These populations, especially the larger species, have been exploited commercially at least since 1879. Coupled with lamprey predation, exploitation was intensive to the extent that the two largest species of the complex had become extinct by the 1950's, and the four next largest species had been drastically reduced in numbers by the 1960's (Wells 1966, cited in Dryer and Beil 1968). Concurrently "bloaters" (*Coregonus hoyi*), the smallest of the chubs, increased in numbers. Their small size allowed them to escape much of the early fishing efforts, and they benefited from reduced predation by lake trout (which were also declining from lamprey predation and over-fishing) (Dryer and Beil 1968). As a consequence, bloaters became the dominant chub in Lake Michigan as of the 1960's. Wells and Beeton (1963), on the basis of catches by the U.S. Bureau of Commercial Fisheries vessel, the R/V Cisco and the occasional examination of commercial catches, estimated that 90-95% of the chubs sampled from Lake Michigan were bloaters, and Baumgart and Schultz (1974) found that 99% of over eleven thousand chubs examined were bloaters. It is therefore fairly safe to assume that for the most part, unidentified coregonids in our sample were bloaters, and they will be treated as such throughout this discussion.

There were 460 bloaters collected from June to December (Appendix 4), which represented 0.59% of the total number of fish collected from Lake Michigan (Table 13). None were captured in Pigeon Lake. Trawling accounted for 85% and included fish of all sizes (40-283 mm). Gill nets were selective for fish 130-280 mm, while the seine caught seven fish (50-80 mm) only in September (Table 18). While some specimens were found at the 0-15 C temperature extremes, 95% of the fish came from water 7-13 C. For the most part, larger bloaters (170-292 mm) were caught in June and July (Appendix 4) when water temperatures were cool, generally during upwellings. Six of these large individuals were gillnetted on the surface at 15 C, but these fish were probably not frequenting such temperatures with any great regularity. Considering the total catch of bloaters, more (135) were captured at station F (15 m -

s.) than at any other station. At shallower stations 3 m to 12 m, decreasing numbers of bloaters were caught. For example, at stations E (12 m - s.), D (9 m - s.), C (6 m - s.) and B (3 m - s.), 82, 69, 59 and 36 bloaters were caught respectively over the sampling season. Such a distribution would be expected, since bloaters prefer the cold, deep waters of Lake Michigan and were only found inshore during spring, fall and upwellings in summer. At reference station C (6 m - s.) and station L (6 m - s.) equal numbers of bloaters (59) were captured.

Substantial numbers of mostly small bloaters (50-80 mm), which made up 62% of the bloater catch, were captured from September through December (Appendix 4). More than half of all the bloaters sampled were caught in October. Water temperatures, especially during October and November, were 11-12 C. Young bloaters feed almost exclusively on zooplankton (Wells and Beeton 1963) and it may be that these bloaters entered relatively warmer waters in search of food. Jude et al. (1979) reported similar findings. Larger bloaters on the other hand, feed nearer the bottom in cooler, deeper waters (Wells and Beeton 1963). Eighty percent of the bloaters we captured had food in their stomachs.

Numbers of YOY found in the fall months indicated fairly significant spawning activity had taken place earlier in 1977. We caught one coregonid larva (13.0 mm) at 15 m station F (s. reference) on 18 June. This larva probably hatched sometime in early May. Wells (1966) found bloater yolk sac larvae captured during April in southeastern Lake Michigan to be 10.8 mm. Unhatched larvae, removed from the egg were 10 mm. Principal spawning times for bloaters are February and March, but it is suspected to occur to some degree throughout the year (Dryer and Beil 1968). Of the adults, one male and three females were found to have ripe gonads in June and July. This is not an accurate indication of the amount of spawning activity during these months however, because spawning apparently occurs in depths of 36-91 m (Scott and Crossman 1973) and our greatest sampling depth was only 21 m. Mid-summer spawning was also indicated by the studies of Jude et al. (1975, 1979).

Of the adult bloaters the sex ratio of males to females was 1:1.39. There has been concern in the past decade that a greatly skewed sex ratio dominated by females would seriously diminish the bloater population. Our data indicate that this trend is perhaps not persisting. In addition our data did not show significant changes in the sex ratio during different times of the year as was found by Dryer and Beil (1968). It should be kept in mind that data collected in this study may not be indicative of the bloater population as a whole which is more concentrated in deeper parts of Lake Michigan.

Johnny Darter --

The johnny darter, a member of the perch family, is widely distributed throughout the Lake Michigan basin (Becker 1976). Johnny darters prey upon small benthic organisms and in turn are eaten by piscivorous fish such as lake trout, burbot, white perch, smallmouth bass and walleye (Scott and Crossman 1973).

Spawning occurs in the spring with the exact time depending upon seasonal conditions (Scott and Crossman 1973). Johnny darters spawn upside down under large rocks, logs, shells, metal cans or other debris; eggs are deposited on the ceiling of the nest (Winn 1958a, Scott and Crossman 1973, Becker 1976). In Lake Michigan near the J. H. Campbell Plant one ripe-running female was captured in early June at station L (6 m - n.). Most (48) johnny darters with well developed gonads were captured in June; only four others with well developed gonads were captured from July-December (Table 34). Forty-eight specimens with moderately developed gonads and 36 with slightly developed ones were captured from June through November. During June larval johnny darters (12.5-22.5 mm) were caught at beach stations T and V. YOY were seined at beach station T (influenced by Pigeon River) on June 27. These data suggest a May or early June spawning period in Lake Michigan near the Campbell Plant. During 1973 in Lake Michigan near the D. C. Cook Power plant, spawning occurred during May and June (Jude et al. 1975). In southeastern Michigan in the Saline River, Winn (1958a) found that johnny darters spawned in May. Becker (1976) reported that spawning usually occurred from April to May in the Lake Michigan basin.

In Pigeon Lake no ripe-running adults were captured, and only three darters with well-developed gonads were seined from June through September (Table 35). In Lake Michigan and Pigeon Lake, 39 and 21 immature johnny darters were captured respectively. A sex ratio of 17 females:22 males was found at 6 m Lake Michigan stations. We would predict, as was found by Jude et al. 1975, that johnny darters will probably colonize and spawn on any appropriate habitat (i.e., riprap) created by the future intake and discharge structures.

A total of 407 johnny darters were captured in this study, 298 from Lake Michigan and 109 from Pigeon Lake (Tables 13 and 14). In Lake Michigan one johnny darter was seined at beach station R (n. discharge); all other Lake Michigan catches occurred in bottom trawls fished at the 6 m to the 21 m contour (stations C, 6 m to H, 21 m - s. transect and station L, 6 m - n. transect) (Appendix 4). In Lake Michigan near the Cook Plant, less than seven johnny darters were seined during 1973-1974 (Jude et al. 1975, 1979).

In Pigeon Lake all johnny darters were seined at beach stations S, T and V with catches of 30, 25 and 54 respectively. Johnny darters in

TABLE 34. Monthly gonad conditions of johnny darters caught in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development	5	1	2	14	3		
	Mod. development	9	1	3	1	9	2	
	Well developed	25				1		
	Ripe-running							
	Spent							
Females	Slight development	1		1	5	4		
	Mod. development	7	1		2	12	1	
	Well developed	23	1				2	
	Ripe-running	1						
	Spent							
	Absorbing							
Immature		6	6	4	10	8	4	1
Unable to distinguish		4	3	6	25	2	1	

TABLE 35. Monthly gonad conditions of johnny darters caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development		7	6	1	5		
	Mod. development	2	1		1	3	11	
	Well developed	1			1			
	Ripe-running							
	Spent							
Females	Slight development					1	2	
	Mod. development					2	7	
	Well developed	1						
	Ripe-running							
	Spent					1		
	Absorbing							
Immature		2	13	5			1	
Unable to distinguish		3	12	9	2	1		

Lake Michigan seemed to avoid very shallow beach waters; whereas, in Pigeon Lake they were captured close to shore. Wave action or lack of food may have inhibited movement of johnny darters into the shallow beach areas of Lake Michigan.

After spawning johnny darters moved into deeper water overlying sand or gravel (Winn 1958a). This pattern appeared to be exhibited in Lake Michigan near the Campbell Plant. During June 116 johnny darters were collected; of these 86 were trawled at station C (6 m - s.), L (6 m - n.) and D (9 m - s). After spawning (July through December) small catches of 8, 8 and 18 occurred at stations C, L and D respectively. In contrast during June at stations E (12 m. -s.) and F (15 m. - s.), 24 and 6 darters respectively were trawled whereas during July to December, 88 were collected at station E and 49 were taken at station F. Maximum catches of johnny darters occurred in June at both the Cook Plant (Jude et al. 1975) and Campbell Plant study areas. Jude et al. (1975) also reported more johnny darters were captured at 6 m than at 9 m during May, June and July.

Size range of johnny darters captured in the Campbell plant vicinity was 14 to 75 mm. Over 84% of all johnny darters caught and 90% of those collected in Lake Michigan were between 40 and 70 mm. Jude et al. (1975) also reported that 40 to 70 mm darters dominated the catch in Lake Michigan near the Cook Plant.

In Pigeon Lake 98 of the total 109 johnny darters caught were between 40 and 70 mm. The length-frequency distribution of johnny darters (composite over both lakes) was bimodal with peaks at 40 mm and 60 mm. These peaks may represent age I and II year classes although Karr (1963) found mean lengths for age I, II and III (36, 50 and 60 mm respectively) were relatively close in the Des Moines River, Iowa. A wider length range (14-72 mm, 0.1-3.2 g) of johnny darters were captured in Pigeon Lake than in Lake Michigan. Our longest darter (75 mm) slightly exceeded the largest reported length (69 mm) given by Scott and Crossman (1973). Growth rates appeared to be uniform between June and August. Apparent growth rates (based upon modal length increases per month) were estimated as 0.36 mm/day at beach station T (influenced by Pigeon River) between June and July and as 0.34 mm/day at beach station V (undisturbed Pigeon Lake) between July and August.

Johnny darters were more susceptible to trawling and seining during the night than during the day (341 at night, 66 during the day) in Lake Michigan. In Pigeon Lake at beach station V (undisturbed Pigeon Lake), where the largest numbers were caught, day and night catches were nearly equivalent (26 day, 28 night). Net avoidance was probably negligible because of the dense vegetation present. Jude et al. (1975) also reported more johnny darters caught at night than during the day.

Johnny darters were captured in the openwater of Lake Michigan at water temperatures primarily between 5 and 11 C; however, in Pigeon Lake they were seined at warmer temperatures, mostly between 11 and 19 C. The range of temperatures at which darters were caught in both lakes was from 1 to 27 C. Jude et al. (1975) reported that largest trawl catches occurred at higher water temperatures of 20-22 C although the range was from 6 to 22 C.

White Sucker --

The white sucker, Catostomus commersoni (Lacepede), is restricted in its range to North America. It is distributed throughout the north-eastern and north-central portions of the continent and is very abundant in many areas (Scott and Crossman 1973). The white sucker inhabits both cold and warm water streams, ponds, lakes and the Great Lakes. Although adaptable to varied types of habitats, they prefer clear, cool water with rock and sand bottoms (Schneberger 1972a). This species is a bottom dweller feeding on aquatic insects, molluscs, algae and fragments of aquatic vascular plants (Stewart 1926, Schneberger 1972a). In most situations, white suckers do not constitute serious competition for food or space with other browsing species (Scott and Crossman 1973).

White suckers spawn in spring. Gonad data from fish collected in Lake Michigan near the D. C. Cook plant suggested spawning occurred in late March, April and May (Jude et al. 1975). As water temperatures reach 10 C, white suckers will migrate into streams from lakes (Scott and Crossman 1973). They spawn in shallow water over gravel, sometimes in rapids. Spawning occasionally occurs in the shallow margins of lakes (Scott and Crossman 1973).

White suckers are marketed as a bait fish, as food for animal and human consumption as well as being occasionally sought as a sport fish. The commercial fishery on this species is located primarily in Green Bay and the northern portions of Lake Michigan. Commercial catch of suckers was nearly 4.5×10^5 kg in 1970 (Wells and McLain 1973).

In Lake Michigan near the Campbell Plant, 294 white suckers were collected during 1977 (Table 13). A smaller number (18) were taken from Pigeon Lake (Table 14). Most suckers in both Pigeon Lake and Lake Michigan were collected in bottom gill nets (303 of 312) (Appendix 4). Catches were greater at night (297 out of a total catch of 312). Suckers appeared to be able to easily avoid seines and trawls since only six fish were caught by these methods. Smaller individuals tended to be caught by seining more readily than larger fish.

White suckers were captured in Lake Michigan and Pigeon Lake during every month fished from June through December (except June in Pigeon

Lake) (Appendix 4). Lake Michigan catches were greatest in July, August and September (Appendix 4). The size of white suckers caught ranged from 70 to 585 mm with 80% 340-510 mm. Only one yearling (70 mm) was taken (25 July). The next smallest individual (240 mm) was probably a 3-yr-old fish according to white sucker age data from various areas complied by Galloway and Kevern (1976). Females we caught were slightly larger than males.

In Lake Michigan smaller individuals were collected at station A (1.5 m - s.) than at deeper stations. This tendency for smaller fish to be found inshore was also noted by Jude et al. (1975) in the vicinity of the Cook Plant. More white suckers were collected at station C (6 m - s.) than at any other station. The largest fish were also found here.

In July, the largest catches of suckers were at shallow stations A (1.5 m - s.), B (3 m - s.) and beach station P (s. reference), while in August some offshore movement was noted since the largest numbers of fish were caught at stations C (6 m - s.) and L (6 m - n.). Also, August was the only month during which white suckers were caught at stations D (9 m - s.) and E (12 m - s.) (with the exception of one found at D in December). During other months no white suckers were found at these deeper stations.

In September, white suckers appeared to have moved back inshore. Most fish were found again at shallow stations A, P, and B, the reference transect.

Temperature-catch data indicated white suckers were found most often at water temperatures of 6-12 C (65.4% of total catch) and 18-22 C (29.3%). No size difference existed between fish caught at these two temperatures ranges.

The inshore-offshore movement of white suckers in Lake Michigan did not appear to be correlated with water temperature. In July, water temperatures at stations A-C (s. transect) ranged from 8.2 to 10.5 C; in August, temperatures at stations A-E ranged from 18.5 to 21.5 C. Thus, the deeper stations in August had water temperatures very similar to the shallower stations thereby affording no inshore refuge of cooler water.

Gonad data for white suckers in July (Table 36) showed a variety of gonad conditions ranging from slightly developed to well-developed with one spent male. Reported spawning times of white suckers from other Lake Michigan locations were late March, April and May (Jude et al. 1975). By the time of sampling in June larvae should have been present if spawning occurred near the Campbell Plant or in the lower reaches of the Pigeon River. However, no white sucker larvae were collected throughout the entire sampling period in Lake Michigan or Pigeon Lake. White sucker larvae reportedly schooled off the bottom and as they grew

TABLE 36. Monthly gonad conditions of white suckers caught in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development		14	2	10			
	Mod. development			18	4		1	
	Well developed		1	30	28		2	1
	Ripe-running							
	Spent		1					
Females	Slight development		5	18	16			
	Mod. development		4	26	8		1	
	Well developed		1	21	15			
	Ripe-running							
	Spent							
	Absorbing							
Immature			1					
Unable to distinguish			2	6	1			

older, moved into shallow vegetated areas where they remained until the end of their first growing season (Hubbs and Creaser 1924). We concluded from our data that spawning does not occur to a large extent in this area or the mouth of the Pigeon River. Undoubtedly more extensive spawning does occur further upstream in the Pigeon River. SCUBA observations in 1978 documented the presence of many YOY white suckers in upstream areas.

Lake Trout --

Lake trout are native to North America and have been widely introduced (Scott and Crossman 1973). This species is mostly found in large, cold lakes. In the Great Lakes, most live in water less than 110 m although they have been caught at 230 m (Van Oosten 1944). Inshore spawning migrations occur during fall with spawning occurring over rocky reefs. During winter, lake trout are distributed throughout the lake. As water warms, lake trout tend to move offshore; however, lake trout are occasionally caught inshore during summer upwellings in southeastern Lake Michigan (Jude et al. 1979).

Prior to the 1950's lake trout populations in Lake Michigan were sustained by natural reproduction. The precipitous decline in the lake

trout population during the 1950's has been attributed to predation by the sea lamprey and to overexploitation by the commercial fishing industry (Smith 1968, Eschmeyer 1956). Current stocks in Lake Michigan are maintained by extensive stocking programs and reasons for the general failure of stocked fish to reproduce are under investigation (Rybicki and Keller 1976). Recent annual catches by sportsmen amounted to more than 4.5×10^5 kg (Wells and McLain 1973). Commercial fishing for lake trout is currently banned in Lake Michigan.

Lake trout (201) were caught in Lake Michigan during all months of the study period (Table 13). Most were caught during July, September and November. One lake trout (640 mm) was caught in Pigeon Lake during June in a bottom gill net (Appendix 4). Five small lake trout (120-330 mm) were caught in trawls in Lake Michigan. No larger fish were caught by trawling which was possibly due to net avoidance. Three lake trout (640-750 mm) were caught with seines in September and October. Surface gill nets caught 29 lake trout (420-810 mm) during July and September. During upwellings lake trout were apparently more evenly distributed in the water column than during the mid-fall to winter months, since in later months no fish were caught in surface nets.

Lake trout were caught in much greater numbers at night (86%) than during the day. This compares closely with findings from research done near the Donald C. Cook Plant where 91% of the lake trout were caught at night (Jude et al. 1979) and indicates a nocturnal inshore migration particularly during fall when most trout were caught. Significant day catches of lake trout occurred only at stations A (1.5 m - s.) and B (3 m - s.) in September, which may have been due to more favorable water temperatures there (8.2 C) compared with deeper stations ($\leq$7.3 C). The preferred temperature for lake trout has been described as 10 C by Daly et al. (1969) and 12 C by Ferguson (1958). Temperature is a major factor determining lake trout distribution. Our data showed that 95% of the total catch of lake trout was in water temperatures of 7-13 C; the overall temperature range at capture was 1.5-19.5 C.

Data on sea lamprey attacks were collected for lake trout. Of the 187 examined, 27% had lamprey scars or wounding, which was comparable to findings by McComish and Miller (1975) who determined that 25% of lake trout sampled in Lake Michigan in Indiana waters had scars or wounds. Jude et al. (1975) reported 22% of the lake trout captured had sea lamprey scars. In the Campbell vicinity, 4% of the scars were fresh indicating some lamprey activity in the area. Preliminary 1978 impingement data showed that sea lampreys are present around the Campbell Plant. The smallest lake trout with a lamprey scar or wound was 432 mm, but this fish had a deformed spine. Probability of lamprey attack for this fish would have been increased due to its age and perhaps due to impaired swimming ability.

There was a positive correlation between length and occurrence of lamprey attacks when data on the number of lake trout with lamprey scars or wounds were examined by length interval (Table 37). These trends were also apparent for lake trout captured in southeastern Lake Michigan near the Cook Plant (Jude et al. 1979). No correlation between the presence of multiple attacks and total length of lake trout was apparent.

Examination of lake trout stomachs showed that this species fed predominantly on alewives when inshore which agreed with findings of McComish and Miller (1975) who found alewife amounted to 93% by volume of lake trout stomach contents. Other prey items they found included smelt, gizzard shad, slimy sculpin, spottail shiner and chironimids. Near the Cook Plant in Lake Michigan alewives were also a primary component of the diet of lake trout (unpublished data, Great Lakes Research Division).

Lake trout spawn in the fall so most fish would be expected to show increasing development over summer and early fall and in fact most males and females caught in November were ripe-running (Table 38). Due to the myriad of questions involved with the success of lake trout reproduction, it is not known whether lake trout successfully reproduce in the area. Of the 185 fish examined for fin clips, eight had no clips. Some evidence exists for lake trout homing (Lawrie and Rahrer 1973), but these eight fish were caught during July and September when the fish had probably not "homed" in on a spawning area.

Lake trout maintain themselves in a relatively stenothermal environment by moving to areas best suiting their temperature preferences. Consequently localized warming in the present and future discharge area could alter distribution during colder months. Our present data from stations L (6 m - n.) and C (6 m - s.) in November showed that catches at these two stations were low and essentially equal.

Black Crappie --

Black crappie are common throughout their range in the Lake Michigan basin (Becker 1976). Their fine flavor makes it quite popular among pan fishermen. This species is taken commercially in gill and trap nets and is an important sport fish over its whole range.

Spawning by crappies usually takes place in May and June, but may be delayed until July during a colder season (Becker 1976). Male black crappie clear shallow nests in water 0.3-0.6 m, then guard and fan eggs that the females lay (Scott and Crossman 1973). Temperatures favorable for spawning lie between 17.8 and 20 C (Schneberger 1972b).

According to Schneberger (1972b), black crappie preferred clear,

TABLE 37. Occurrence of sea lamprey scars on lake trout caught near the J.H. Campbell Plant, eastern Lake Michigan, 1977.

Length interval (mm)	Total no.	No. scarred	Percent scarred	No. scars per fish			
				1	2	3	4+
800-849	6	4	67.0	2	2		
750-799	25	11	44.0	9	1		1
700-749	72	21	29.0	17	3		1
650-699	51	12	24.0	9	3		
600-649	18	1	6.0	1			
550-599	3	0	0				
500-549	5	0	0				
450-499	1	0	0				
400-449	2	1	50.0		1		
<400	5	0	0				
Total	188	50	27.0				

TABLE 38. Monthly gonad conditions of lake trout caught in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development	1	1		2		1	
	Mod. development	1	5		19		1	
	Well developed		17		49			
	Ripe-running						11	
	Spent		1					
Females	Slight development		1		2		1	1
	Mod. development		1					
	Well developed		14	1	47	1		
	Ripe-running						4	
	Spent							
	Absorbing							
Immature		2						
Unable to distinguish			1		1			

deep, cool water with hard-sand and gravel (not weedy) bottoms. Scott and Crossman (1973) on the other hand, reported that this species was associated with abundant growths of aquatic vegetation and sandy to mucky bottoms. Our data support the latter authors. All 183 specimens obtained in this study were collected from Pigeon Lake and 66% came from beach station T (influenced by Pigeon River) which has a mucky bottom and supports high densities of aquatic vegetation in the summer.

Nearly equal numbers of black crappie were obtained in day and night sampling in Pigeon Lake. Seining was the most effective sampling method, taking 82% of the black crappie and gill nets accounted for the rest. Crappies were collected during every month of the study, June - December. Three-fourths of the fish were immature; most were found in water 1 m deep or less. Black crappies feed on invertebrates in shallow water until their third year of life at which time they become mainly piscivorous (Scott and Crossman 1973). Eighty-nine percent of the black crappies in our samples had food in their stomachs. This species was found most often in 17-23 C water with largest numbers caught in July (85), August (37) and September (34). Size extremes of crappies caught were 25 and 270 mm (Appendix 4).

Bluegill --

The native range of the bluegill is restricted to the freshwaters of eastern and central North America (Scott and Crossman 1973). In the Lake Michigan drainage basin, bluegills are a common sport fish (Becker 1976). In Michigan spawning begins during June and often extends through autumn (Bennett 1962). Spawning occurs when water temperatures reach 19.4 to 26.7 C. Males usually dig nests in sand or gravel; often the nests are combined with leaves and sticks (Snow et al. 1970). In the vicinity of the Campbell Plant, of 139 bluegills collected, 134 were immature specimens, while five were mature bluegills captured during August through November (Table 39).

Bluegills inhabit warm water with much rooted vegetation where they feed on zooplankton, aquatic insects and vegetation (Snow et al. 1970, Becker 1976, Werner and Hall 1976). Most bluegills (178) were caught in Pigeon Lake; only four were collected from Lake Michigan. All bluegills (182) were seined at beach stations (T, V, S, R and Q) where 88, 68, 22, 3 and 1 fish respectively were captured. Station T (influenced by Pigeon River) and V (undisturbed Pigeon Lake) are weedy areas in Pigeon Lake typical of bluegill habitat while station S (influenced by Lake Michigan) is a less weedy station. Stations Q and R are beach stations in Lake Michigan south and north of the present discharge canal. Size range of bluegills caught was 20-177 mm (1 to 144 g) (Appendix 4). Most (172) bluegill had lengths between 20 and 54 mm and weights between 0.1 and 2.2 g. About 160 fish 22-50 mm were probably YOY based on age-length data (Carlander 1977). Most young bluegills were captured at shallow beach stations from August through November.

TABLE 39. Monthly gonad conditions of bluegill caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development					1	2	
	Mod. development					1		
	Well developed							
	Ripe-running							
	Spent							
Females	Slight development			1				
	Mod. development							
	Well developed							
	Ripe-running							
	Spent							
	Absorbing							
Immature		2	9	32	35	30	26	
Unable to distinguish		1						

Only four bluegills (YOY) were captured in Lake Michigan; all were seined during October at beach stations R and Q which are sometimes influenced by the present thermal discharge. Our 1978 observations of the discharge canal showed the presence of many species of fish, including bluegill. We are thus of the opinion that the bluegills observed at Lake Michigan beach stations R and Q came from the discharge canal. Snow et al. (1970) also reported that bluegill often congregate below discharges of power plant condensers during winter. In Lake Michigan near the Cook Plant only ten bluegills were captured during 1973 (Jude et al. 1975). Our data indicate that bluegills do not flourish in Lake Michigan, but this fish does adapt well to eutrophic waters such as Pigeon Lake.

Water temperatures between 15.6 and 26.7 C are best for bluegill growth (Rounsefell and Everhart 1953). In the Pigeon Lake and Lake Michigan vicinity bluegills were captured at water temperatures ranging from 9-27 C. Most (166) were seined at water temperatures between 11-23 C. Maximum lethal temperature is thought to be about 35 C for bluegill (Snow et al. 1970).

Gizzard Shad --

Gizzard shad, a member of the herring family, inhabit eastern North America (Scott and Crossman 1973). In the Lake Michigan drainage basin,

they are most abundant in the eastern and southern areas (Becker 1976). This rapidly growing species serves as a forage fish only until the middle of its second year (Bodola 1966). Gizzard shad are often considered a pest species because of their attraction to inlets and outlets of industrial plants and their occasional spring, fall or winter die-offs (Bodola 1966). Their flesh is soft, tasteless and bony but can be used as fertilizer and livestock feed (Miller 1960).

Spawning occurred in Lake Erie during early June into July, being most intensive in mid-June when water temperatures reached 19.5 C (Bodola 1966). Miller (1960) reported spawning taking place in the U.S. from mid-March through most of the summer although the bulk of the population in warm temperate areas spawned during April, May and June. He also reported that gizzard shad generally spawn with rising water temperature within the range of 10 to 21.1 C. Gizzard shad (age II) spawn in masses at the surface of sloughs, ponds, lakes and large rivers while rolling and tumbling around each other. Eggs sink and adhere to plants or any other object they contact (Miller 1960). Inspection of gonads of gizzard shad captured near the Campbell Plant gave no clear indication when spawning occurred in the area (Tables 40 and 41). One spent male was captured in August. Specimens with well developed gonads from Lake Michigan were captured in November. No ripe-running individuals were captured. YOY were collected as early as July at Lake Michigan beach stations Q (s. discharge) and later at stations R (n. discharge) and P (s. reference) which is indicative of spawning before July in Lake Michigan. Ripe-running gizzard shad were not captured in Lake Michigan near the D. C. Cook Power Plant either (Jude et al. 1979). In Pigeon Lake all seven gizzard shad captured had either moderately developed (four fish) or slightly developed (three fish) gonads (Table 41).

Gizzard shad inhabit a wide variety of habitats such as large rivers, reservoirs, lakes, swamps, borrow pits, bayous, estuaries and temporary flood water pools (Miller 1970). They are essentially an openwater planktivore although benthic organisms have been found in their guts (Scott and Crossman 1973, Jude 1973). In Lake Michigan and Pigeon Lake near the Campbell Plant 181 gizzard shad, ranging from 57 to 506 mm, 0.1 to 1990 g, were captured by seine and gill net. No gizzard shad were trawled; Jude et al. (1979) report large adults seem to avoid trawl nets. The length-frequency distribution was bimodal with peaks at 60 mm and 420 mm (Appendix 4). Most shad (105) were captured in gill nets set at the 1.5 to 9 m contours in Lake Michigan. Eighty-six were captured in bottom gill nets. Most (146) gizzard shad were captured at night, as they were near the Cook Plant (Jude et al. 1978). Along the southern transect in Lake Michigan, shad were captured at stations P (beach), A (1.5 m), B (3 m), C (6 m), D (9 m), where 6, 40, 21, 11 and 6 fish were caught respectively. Directly off the Campbell Plant, gizzard shad were captured at beach stations R and Q (s. and n. discharge), and

TABLE 40. Monthly gonad conditions of gizzard shad caught in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development			7	4		6	
	Mod. development				4		22	
	Well developed						12	
	Ripe-running							
	Spent			1				
Females	Slight development		1	4	7	1		
	Mod. development				2		11	
	Well developed						35	
	Ripe-running							
	Spent							
	Absorbing							
Immature			1		32	11	3	
Unable to distinguish			1	1	1			

TABLE 41. Monthly gonad conditions of gizzard shad caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development		1	1				
	Mod. development				2			
	Well developed							
	Ripe-running							
	Spent							
Females	Slight development			1				
	Mod. development				2			
	Well developed							
	Ripe-running							
	Spent							
	Absorbing							
Immature								
Unable to distinguish								

station L (6 m coutour) where 34, 30 and 27 fish respectively were taken. More were seined at the thermally influenced beach stations Q and R (63 fish) than at the reference station P (6). We feel that significant spawning and production of gizzard shad is occurring in the Grand River. We observed thousands of 2-3 cm gizzard shad along the docks in Grand Haven during the summer of 1977. The Campbell discharge canal is also thought to be prime spawning habitat for shad. Most YOY and many of the adults are thought to have been derived from one of these two sources. Jude et al. (1979) reported seine catches during 1973 and 1974 consisted of immature gizzard shad that seemed to congregate in the beach zone in May and June and from October through December.

No gizzard shad were captured during June near the Campbell Plant. Most (144) were caught during September (50 fish) and November (94 fish) when gizzard shad characteristically move into shore or school around the mouth of rivers (Scott and Crossman 1973). Jude et al. (1975) reported along shore movement of gizzard shad at least from August to October. At the Campbell Plant gizzard shad were impinged primarily during October through December. Gizzard shad captured during field sampling were most abundant during November as were impinged gizzard shad. In Lake Erie near Detroit Edison's Monroe Power Plant, peak impingement of gizzard shad during certain periods has been attributed to: 1) turbidity, 2) changes in water temperature, 3) schooling behavior and 4) variations in intake pump speed (Eisele and Malaric 1976). Only seven gizzard shad were captured in Pigeon Lake bottom gill nets during the entire sampling period, six fish at 6 m station M (influenced by Lake Michigan) and one fish at 1 m station Y influenced by Pigeon River. Many more gizzard shad must pass through Pigeon Lake, possibly in the surface layer or in areas not sampled. They may also school around the intake canal as they do around other industrial inlets and outlets (Miller 1960).

Eighty-one percent of the gizzard shad were captured at water temperatures between 11 and 15 C with the range being from 9 to 21 C. Near the Cook Plant in southeastern Lake Michigan most gizzard shad were captured in water that ranged from 11 to 19 C. Captures during these periods probably reflected seasonal migration of gizzard shad rather than water temperature preference.

Rock Bass --

Rock bass, a member of the sunfish family, is native to the freshwaters of eastern central North America (Scott and Crossman 1973). Within the Lake Michigan drainage basin, rock bass are common (Becker 1976). They are fished commercially in the Great Lakes and Mississippi River, and are a sport fish elsewhere (Scott and Crossman 1973).

TABLE 42. Monthly gonad conditions of rock bass caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development	1	10	7	3	1	1	
	Mod. development	1	4			1	1	
	Well developed							
	Ripe-running							
	Spent							
Females	Slight development	2	10	10			1	
	Mod. development		2			3		
	Well developed	1						
	Ripe-running	2						
	Spent							
	Absorbing							
Immature		20	22	20	3	1		
Unable to distinguish			4	4	2			

This common pan fish prefers clear, cool water over a gravel or rocky bottom with some vegetation although it inhabits many types of water (Becker 1976). Rock bass spawn in late May and early June at water temperatures between 15.6 and 21.1 C (Becker 1976). In Pigeon Lake near the Campbell Plant, immature (66) and mature (61) specimens were caught from June through November (Table 42). Two "ripe-running" females were captured in June when spawning probably occurred. Rock bass, like most centrarchids, are nest builders. Coarse gravel is the preferred bottom type for nest building although marl, bedrock and dense beds of aquatic plants have also been reported as nesting sites (Breder and Rosen 1966).

In our study all rock bass (173) were captured in Pigeon Lake at beach stations S (influenced by Lake Michigan), T (influenced by Pigeon River) and V (undisturbed Pigeon Lake). About twice as many rock bass were seined at station T, which is more influenced by the Pigeon River than stations S or V. The majority (128) of the rock bass captured were 45 to 94 mm long, weighed between 1.9 and 18.6 g and were probably age I and II rock bass (Carlander 1977). One 40 mm YOY was captured in October. The range in length of all rock bass collected was 33 to 199 mm; weights were between 1.1 and 161 g. The weights from size classes are similar to other specimens from Michigan and Wisconsin (Hile 1941, 1942, Beckman 1948).

Rock bass in the present study were captured predominately at night (149 night captures, 24 day captures). Other studies have shown that this species was equally nocturnal and diurnal (Keast and Welsh 1968) or inactive at night (Emery 1973). Net avoidance may have caused lower catches in our day nets.

Most (145) rock bass were seined at water temperatures between 15 and 23 C, although the range was between 9 and 23 C. Smaller fish (45-94 mm) were captured during warmer months (June through September) at temperatures of 15-23 C.

Brook Silverside --

The brook silverside is widely distributed throughout the freshwaters of central North America (Scott and Crossman 1973). The silverside is commonly found within the southern two-thirds of the Lake Michigan basin, although here they approach the northern limit of their range (Becker 1976).

Brook silversides are small forage fishes having a 1 yr life cycle (Hubbs 1921). Spawning usually occurs during early summer when water temperatures reach 20 to 22.7 C (Hubbs 1921, Becker 1976). Eggs, having a long adhesive filament, become attached to aquatic vegetation such as Scirpus and Potamogeton (Bailey 1968). Spawning may also occur over gravel areas (Hubbs 1921).

During our study 159 brook silversides were collected; all but one were collected in Pigeon Lake. Many (59) of the specimens captured from the Campbell area were immature (Table 43). One female with well-developed gonads was captured in June. The date of spawning cannot be estimated from these data.

Silversides reside in the upper water layers of lakes, rivers and large streams (Hubbs 1921, Becker 1976). In the vicinity of the Campbell Plant all (159) brook silversides were seined at Pigeon Lake beach stations T (influenced by Pigeon River), V (undisturbed Pigeon Lake), S (influenced by Lake Michigan) and Lake Michigan beach station P (s. reference) where 92, 42, 24 and 1 were captured respectively. Fifty-eight percent of all silversides were seined at station T which is a very productive, weedy area near the Pigeon River.

At Pigeon Lake beach station V, 26% of the silversides were captured, while at station S, which is influenced by Lake Michigan, only 15% of the silversides were captured. In Lake Michigan only one fish (40 mm) was caught (Appendix 4). Pigeon Lake, a more productive and less harsh environment than Lake Michigan, appeared to be a more suitable habitat for the brook silverside. Jude et al. (1975) did not catch brook silversides during 1973 in the inshore waters of

TABLE 43. Monthly gonad conditions of brook silversides caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development			2	4	2		
	Mod. development			2		1	1	
	Well developed							
	Ripe-running							
	Spent							
Females	Slight development							
	Mod. development				2			
	Well developed	1						
	Ripe-running							
	Spent							
	Absorbing							
Immature			24	26	3	2	4	
Unable to distinguish				1	7	1		

southeastern Lake Michigan. A few were caught in later years.

Silversides captured ranged from 28 to 102 mm and 0.1 to 4.1 g. The distribution of lengths appeared normal with a peak at 60 mm. Most (136) silversides were between 35 and 84 mm long and weighed 0.4 to 2.8 g. Growth of silversides is extremely rapid (Scott and Crossman 1973). Average YOY growth rates from modal lengths were estimated to be 0.81 mm/day from July through September in the vicinity of the Campbell Plant. A higher rate (1.07 mm/day) was estimated for the period July through August, than for the August-September period.

More brook silversides were captured at night (124) than during the day (35) (Appendix 4). Perhaps silversides are more easily captured at night as Hubbs (1921) reported that at night adults lie quiescently below the surface while during the day they swam about surface waters. Most of this diel difference in catch is undoubtedly attributable to daytime net avoidance. Silversides (134 of 159) were captured primarily from July through September. Water temperature at capture sites ranged from 9 to 27 C although more (87) silversides were caught between 16 and 17.9 C than at any other temperature.

Ninespine Stickleback --

The ninespine stickleback is distributed throughout the northern hemisphere in both fresh and salt water (Scott and Crossman 1973). In Lake Michigan, this species is more common in the northern part of the lake, with some indication of an increased abundance in the southern and east central portions in recent years (Wells and McLain 1973). Ninespine stickleback reportedly prefer a cool, quiet water habitat (Becker 1976).

Spawning of ninespine sticklebacks is reported to occur in June and July in Lake Superior (Griswold and Smith 1973) and Crooked Lake, Indiana (Nelson 1968b). These authors suggested a spawning season of approximately 8 wks. Multiple spawning within a season occasionally occurs (Scott and Crossman 1973). Maturity in most ninespine sticklebacks was reached by age II in Lake Superior, although earlier maturity at age I was quite common (Griswold and Smith 1973). Reproductive behavior similar to the other gasterosteids is reported. The male constructs a nest of vegetation and debris which is held together by a kidney secretion that hardens on contact with water (McKenzie and Keenleyside 1970). After the female is enticed into the nest and deposits the eggs, they are fertilized by the male who then guards the nest.

The present study indicated that ninespine sticklebacks were common in the area of the Campbell Plant, since 134 specimens were caught during 1977 sampling. Nearly all (132 out of 134) ninespine sticklebacks were trawled from Lake Michigan; one was also seined. Only one 60 mm specimen was collected in seine hauls in Pigeon Lake in June. This species was apparently most abundant during June since 87 sticklebacks were trawled in Lake Michigan at depths ranging from 6 to 18 m. Subsequent lower catches from July-December (Appendix 4) may indicate movement of sticklebacks offshore to deeper waters during these months. Monthly gonad condition data summarized in Table 44 suggested the possibility that presence of sticklebacks in the area during June and July may be due to spawning. Many female sticklebacks caught in June and July had well developed to moderately developed ovaries. Except for the occurrence of a single stickleback seined at Lake Michigan beach station Q (n. discharge) in June, the ninespine stickleback was notably absent from the nearshore (less than 6 m) waters of Lake Michigan near the Campbell Plant.

Temperatures at time of capture ranged from 4-24 C, with 94% of all sticklebacks caught between 4 C and 12 C, which agreed closely with findings from Crooked Lake, Indiana where adults were caught in 5-25 C waters with most caught from 6-12 C (Nelson 1968b).

In agreement with observations by Jude et al. (1975) and Griswold

TABLE 44. Monthly gonad conditions of ninespine sticklebacks in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development	13	2	1	5			
	Mod. development	7		2	5			
	Well developed	2						
	Ripe-running							
	Spent							
Females	Slight development		1	2				
	Mod. development	11						
	Well developed	36	3		1			
	Ripe-running	1						
	Spent							
	Absorbing							
Immature		1	3	4	3	3	2	
Unable to distinguish		6	7					

and Smith (1973) lower catches of ninespine stickleback occurred during day sampling, with only 23 of the 134 specimens in the present study caught during the day (Appendix 4). This observation, along with the absence of sticklebacks from water less than 9 m during the day, suggested a limited offshore movement during daylight hours.

Although 1977 data suggested that Pigeon Lake was seldom utilized by ninespine sticklebacks (only one caught), preliminary observation of 1978 data as well as 1975 impingement data (Consumers Power Company 1975) showed that sticklebacks were quite common in Pigeon Lake during spring. The reason for their presence is not yet certain, but the debris-covered bottom of Pigeon Lake as well as its protected nature, may make it an optimum spawning area. Spawning in Pigeon Lake was evidenced by the occurrence of stickleback larvae in June at Pigeon Lake beach station S (influenced by Lake Michigan). Spawning probably occurred sometime in May.

In situations where they are abundant, ninespine sticklebacks are important as forage for other game species (Scott and Crossman 1973). In the area of the Campbell Plant this species has been found in the stomachs of yellow perch, however its importance to other species is yet to be determined.

Brown Bullhead --

The native distribution of brown bullhead is restricted to fresh waters and, rarely, brackish waters of eastern and central North America (Scott and Crossman 1973). It is dispersed throughout the Lake Michigan basin (Becker 1976) and generally inhabits weedy and deeper waters of lakes and sluggish rivers (Hubbs and Lagler 1964). The brown bullhead makes up the major portion of the commercial catch of all bullhead species and may provide some sport for fishermen as it readily takes bait (Scott and Crossman 1973). It is well adapted to pond culture, but has not been commercially raised because of low demand (Bardach et al. 1972).

The brown bullhead was a common species in Pigeon Lake where it accounted for approximately 0.58% of the total catch. None were caught in Lake Michigan. Of the 120 specimens collected, 82 were caught at beach station T (influenced by Pigeon River), 23 at openwater station Y (undisturbed Pigeon Lake), 9 at openwater station M (influenced by Lake Michigan) and 6 at beach station V (undisturbed Pigeon Lake). Located in areas of soft bottom with abundant aquatic vegetation near Pigeon River, stations T and Y were the most preferred habitats for the brown bullhead in Pigeon Lake. Beach station V which consisted of extensive shallow water with moderate aquatic vegetation was only sparingly used by this species. A small number of large brown bullheads seemed to remain during most of the sampling period in the relatively deep waters of station M. One or two specimens were collected at this station every month except in July. Beach station S (influenced by Lake Michigan) with a sandy bottom and relatively deep water close to the shoreline, was apparently not used as a spawning or nursery ground. No brown bullheads were collected there.

YOY brown bullheads ranging from 23-79 mm were restricted to shallow areas and were collected only by seine. Of the 34 adults, 32 were caught by bottom gill nets and two by beach seine. Raney and Webster (1939) reported that adult brown bullheads moved at night from deeper waters into shallow bays. Similar movements probably occurred in Pigeon Lake, but large fish often successfully avoided the seine.

Brown bullheads spawned from March to May in Florida and in June in Michigan and Wisconsin (Carlander 1969). Spawning may continue through September in Alabama (Swingle 1957). Both parents guard the nest and young (Breder and Rosen 1966). Our gonad data (Table 45) showed that spawning in Pigeon Lake took place in May and June in areas not influenced by Lake Michigan, with beach station T apparently being the most important spawning ground.

YOY first appeared in the July collection which included 30 specimens measuring from 23-62 mm in total length (Appendix 4). This

TABLE 45. Monthly gonad conditions of brown bullheads caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development	2		3	1	3	3	
	Mod. development					1	1	
	Well developed							
	Ripe-running							
	Spent							
Females	Slight development		2				3	
	Mod. development	2				8	4	
	Well developed	1					2	
	Ripe-running							
	Spent	2						
	Absorbing							
Immature			30	22	5	7	2	
Unable to distinguish								

sample represented the highest monthly catch of YOY brown bullheads during our study. Catches of YOY generally continued to decrease from August to November as these fish became less abundant and less vulnerable to the seine. Twenty-two YOY were caught in August, five in September, ten in October and two in November (Appendix 4). Dispersal of YOY following a change in schooling behavior may partially explain the sharp decline in catch observed in September.

In Cayugua Lake, New York, YOY brown bullhead spawned in June grew to an average length of 36.9 mm by late July, 42 mm in August and 68.0 mm in October (Raney and Webster 1939). The Pigeon Lake YOY showed comparable growth reaching an average length of 38.2 mm, 44.0 mm and 66.0 mm for the above three months respectively. The five YOY caught in September were larger fish, ranging from 67 to 82 mm in size.

Adult brown bullheads were found in all monthly collections from Pigeon Lake. Catches of adults in June (7 specimens), in October (9) and in November (13) were higher than those of July (2), August (2) and September (1) (Appendix 4). This change in seasonal distribution may be related to parental care activity. In July, August and September, adult brown bullheads which were guarding their young were probably less active and therefore less likely to be caught in our fishing gear. High catches of brown bullhead at night (112 out of 120 specimens) agreed

with the known nocturnal habit of this species (Scott and Crossman 1973).

Only two brown bullheads in the 100-200 mm size group were represented in our collections (Appendix 4). Size segregation between intermediate and large brown bullheads may occur with intermediate sized fish in well protected and less sampled areas. Brown bullheads were never collected in Lake Michigan.

Water temperatures at the time of capture for brown bullheads ranged between 8.0 and 23.4 C. YOY were mostly collected at higher temperatures (16-23.4 C), while adults were caught at water temperatures between 8.0-12.0 C. Twenty-five of the 35 adults and YOY collected between 8.0-12 C contained food in their stomach, indicating they were actively feeding at this temperature range.

Brown bullheads appeared to have sucessfully dominated the other two species of bullheads in Pigeon Lake (see Black and Yellow Bullhead sections), probably because browns are best suited for this type of habitat. In a study on the fishes of Ohio, Trautman (1957) indicated that the black bullhead was unable to invade cool, deep waters inhabited by the brown bullhead, and that abundance of the yellow bullhead in an area may be limited by the presence of the other two species.

The brown bullhead was reported to hybridize with the black bullhead in western Lake Erie and in small impoundments in Ohio in areas where only submarginal habitats existed for one or both species (Trautman 1957). Hybridizaton probably also occurred in Pigeon Lake as we occasionally found specimens possessing intermediate characters between the two species.

Northern Pike --

The northern pike is found throughout the northern hemisphere, being widely introduced from its native North America (Scott and Crossman 1973). It is common throughout the Lake Michigan basin (Becker 1976). Northern pike are frequently found in cool to warm lakes, ponds and sluggish rivers. They often prefer shallow, weedy areas during the spring and fall and deeper, cooler water during summer (Hubbs and Lagler 1958). Most of the Pigeon Lake/Pigeon River area represents excellent habitat for northern pike and in addition, it offers large, shallow, weeded areas and the Pigeon River floodplain which pike undoubtedly required for successful spawning. Our catch data combined with results from the mark and recapture study (see MARK AND RECAPTURE) showed that a large population of northern pike existed in Pigeon Lake. Michigan Department of Natural Resources personnel have collected northern pike for spawning stock from Pigeon Lake because of the abundance of this species in the lake (John Trimberger. Personal communication, Michigan Department Natural Resources, Grand Rapids, Michigan).

Pike were caught during every month of the study period, June through December. Although none were caught in Lake Michigan, Campbell Plant personnel reported that ice fishermen caught northern pike near the jetties during winter months. Heated water is pumped to the jetties to keep the intake area ice-free and pike might be attracted there because of higher water temperature or a more abundant food supply.

Pike were caught at all stations in Pigeon Lake. Similar numbers of pike were caught at the two openwater gill netting stations, M (influenced by Lake Michigan) and Y (influenced by Pigeon River), while more pike were caught at beach stations S (influenced by Lake Michigan) and T (influenced by Pigeon River) than at V (undisturbed Pigeon Lake). Station V is located in a large shallow area, while at the other two stations the bottom is steep with dropoffs. The reason for higher catches at beach stations S and T could be a preference for habitat near deep water. Pike were caught by electrofishing in large numbers at station V between the seining area and the deeper water offshore.

Total catch of northern pike using seines and gill nets during the study was 113 fish; monthly catches varied from 7 to 29 fish (Appendix 4). More pike per month were caught in gill nets from September-December than from June-August. This could indicate greater activity as water temperature cools, but does not support the idea that pike move to cooler water during summer months.

Large pike were caught throughout the year in both seines and bottom gill nets. Although no age determinations were done, it is possible to make reliable estimates of growth during the study period based on catch data. Five pike (40-84 mm) were caught in June which were probably YOY. Other pike caught in June were at least 300 mm. Carbine (1945) found pond-reared YOY pike as large as 446 mm by October 14. It was more likely that the 300 mm pike caught in June was a yearling. Size ranges for YOY northern pike in Pigeon Lake were as follows: July: 82-177 mm; August: 129-232 mm; September: 209-252 mm; October: 246 mm (one fish); November: 170-330 mm. High growth rates found by Carbine were probably due to warmer water temperatures, abundant food and a lack of large predators. Growth values obtained for Pigeon Lake pike were high relative to Carbine's data. Rapid growth by Pigeon Lake pike could be due to an abundant supply of food and warm water temperatures. Pigeon Lake served as a spawning area for some typical Lake Michigan species (alewives, spottails) as well as for resident Pigeon Lake species and does have large numbers of small prey fish suitable for YOY pike.

Two YOY northern pike (102, 124 mm) caught during July were feeding on alewives. Larger northerns find a seasonal supply of food from migrating salmonids entering Pigeon Lake. An unidentified salmonid (375 mm, 300 g) was eaten by a pike (835 mm) caught on 18 October.

TABLE 46. Monthly gonad conditions of northern pike caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development	4	7	4	2	1	1	1
	Mod. development				3	3	4	8
	Well developed					1	1	
	Ripe-running							
	Spent							
Females	Slight development	2	1	6	1			
	Mod. development	1		4	4	2	3	
	Well developed						1	6
	Ripe-running							
	Spent		1					
	Absorbing							
Immature		5	7	1	2		1	
Unable to distinguish		1	1	1			18	3

Pigeon Lake species eaten by pike included: grass pickerel, lake chubsucker and largemouth bass.

Northern pike up to 933 mm were caught during regular sampling. The largest individual weighted 5300 g. Age analysis for large pike is being considered for the 1978 study.

Northern pike gonads were found to be at some stage of sexual development from June-December (Table 46). Spawning generally occurs just after the ice leaves and has been reported during April in Michigan (Carbine 1942). All adult pike captured had spawned by the time the study began in late May-early June. Some YOY showed such gonadal development in November that they would be expected to spawn the following year. This rapid development has been noted by Navratil (1954), Calderon-Andreau (1955) and Fedin (1958) (as cited in Machniak 1975) and is regarded as exceptional. Northern pike appeared to be growing and propagating well in Pigeon Lake.

Minor Species

Bowfin--

The bowfin is the only surviving member of an ancient fish family that has long been extinct (Hubbs and Lagler 1964). Bowfin occur only

in North America and inhabit swampy, vegetated bays of warm lakes and rivers (Scott and Crossman 1973). In Michigan, the northern limit of their distribution reaches the southern portion of the Upper Peninsula (Becker 1976).

Seventy bowfin were collected in this study, all from Pigeon Lake. Of these, 34 were caught by gill net at Pigeon Lake openwater station M (influenced by Lake Michigan), 33 by gill net at Pigeon Lake openwater station Y (influenced by Pigeon River) and three by seine, one from each of the three beach stations. Although the bowfin was mostly caught in deeper parts of the lake, it also frequented shallow areas. During electrofishing several individuals were seen in the shallow areas, but evidently most were quite successful in escaping the beach seine. Our catch included mostly larger fish with a size range from 358 to 720 mm (Appendix 4). Young bowfin are believed to remain in deep water or in areas with dense vegetation and are therefore rarely seen after the schools disperse (Scott and Crossman 1973).

Bowfin were caught over a broad range of water temperatures (2.4-26.9 C) with most catches occurring between 8.0 and 19.0 C. Station M, which remained relatively warm during colder months, served as a winter refuge for the bowfin. Fifty per cent of the bowfin catch at this station was made in December at water temperatures between 2.4 to 3.2 C. No bowfin were collected in our day gill net set in December at station Y (influenced by Pigeon River) where water temperature was only 0.5 C. Station Y and probably other areas not disturbed by the inflow of Lake Michigan waters were preferred habitats during warmer months.

The bowfin, which represented 0.34% of the Pigeon Lake catch, was one of the important predators in this lake. Since bowfin are not a popular game fish (Hubbs and Lagler 1964), we believe their population has remained high in Pigeon Lake. This species was reported to prey on all kinds of fish and may become a serious competitor and predator of sport fishes (Scott 1938, Scott and Crossman 1973). Our data, however, did not permit any evaluation of the influence of this species on the sport fishes of Pigeon Lake. Most bowfin collected (67%) had empty stomachs, while stomach contents of the remaining 33% included alewives, gizzard shad, spottail shiner, unrecognizable fish and remains of other animals.

Aquarium observations suggested that bowfins used scent as much as sight for feeding (Scott and Crossman 1973). Carlander (1969) reported that the bowfin often feeds at night. Our data, which included 47 fish caught at night and 23 during the day (Appendix 4), indicated that the bowfin tended to be more nocturnal than diurnal. In December, however, for unknown reasons, more bowfin were caught during the day (10) than at night (7).

TABLE 47. Monthly gonad conditions of bowfins caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development			3	2		1	
	Mod. development	1		2	3	6	1	6
	Well developed							3
	Ripe-running							
	Spent							
Females	Slight development			1				
	Mod. development			2	4	1		6
	Well developed	2		1	3	8	7	2
	Ripe-running							
	Spent	1	1					
	Absorbing							
Immature								
Unable to distinguish					1	2		

Bowfin spawn in April in Illinois, in June in Ontario and from April to July over its entire range (Carlander 1969). The male builds the nest in shallow, vegetated areas of lakes and streams and guards the young until they reach approximately 102 mm in length (Scott and Crossman 1973). Our gonad data (Table 47) indicated that spawning in Pigeon Lake probably took place in June and July.

The bowfin was represented in all monthly samples (Appendix 4). Low catches in June and July were perhaps related to spawning activities. During this period most bowfin likely remained in well protected areas guarding their nest or young and were therefore able to avoid gill nets and seines. Monthly catches ranging from 9 to 17 fish during the period August-December (Appendix 4) increased markedly over those of the previous 2 months. Adult bowfin probably left their young in August, September and October and became more vulnerable to our fishing gear during this period and later months as they resumed a more active search for food.

Bowfin probably rarely entered Lake Michigan. No bowfin were caught in Lake Michigan near the Campbell Plant and only one specimen was collected in 1973 in a similar study at the Cook Plant in the southeastern part of the lake (Jude et al. 1975).

Coho Salmon --

Coho or silver salmon naturally occur in the Pacific Ocean and tributaries from Montery, California to Point Hope, Alaska (Scott and Crossman 1973). The introduction of coho began in Michigan during 1966 when 660,000 smolts were planted in three Lake Michigan tributaries (Wells and McLain 1973, Becker 1976). Coho were selected to provide a put-and-take sport fishery and to prey upon the abundant alewives (Tody and Tanner 1966, Parsons 1973). The Campbell Plant is located 21 km from the Grand River, 47 km from the Muskegon River and 19 km from the Black River where 210,000, 175,000 and 100,000 smolts respectively were released during 1977. Most of the released coho were between 100 and 152 mm (M. Patriarche, personal communication, Institute of Fisheries Research, University of Michigan, Ann Arbor, Michigan).

Although a 1933 planting of coho in Lake Erie failed to establish a self-sustaining population, natural reproduction of coho in Lake Michigan tributaries has been documented (Parsons 1973). Studies are under way to determine the extent of natural reproduction (M. Patriarche, personal communication). Normally, adult coho return to their natal streams to spawn after 18 months in the Great Lakes or ocean. Upstream migrations of adults begin during early fall with actual spawning beginning in October and November in swift, shallow gravelly areas (Godfrey 1965). From early March to late July fry emerge from gravel beds (Tody and Tanner 1966). A few may migrate downstream but generally they reside in shallow gravel areas of the natal stream for 1 yr. Yearling coho smolt then begin their downstream migration in March or April.

The upper reaches of the Pigeon River in the vicinity of the Campbell Plant have not been examined for presence of coho fry. Six mature adults were captured during the spawning season (September and November), but only one coho, a male with slightly developed gonads, was captured in Pigeon Lake. The other coho were captured in Lake Michigan with bottom gill nets at depths of 3, 6, 9 and 12 m. Two factors may account for the low number of adults caught near the Campbell Plant: (1) the area is not particularly close to any of the tributaries where coho are planted annually and (2) the Pigeon River has an organic, muddy bottom which may not be conducive to successful spawning.

Fifty-five coho salmon were caught during 1977. Of these, 85% were caught during June at all Lake Michigan beach stations (P, Q and R) during night sampling. Coho caught during the June period were small immature fish (88-113 mm, 5.5-11.9 g). Tody and Tanner (1966) reported that for the first few months of summer coho remained close to shore where they fed on small forage fish and crustaceans. June data showed evidence of inshore habitation by small coho. Although these coho (88-113 mm) were smaller than the average planted coho (100-152 mm),

most coho probably originated from stocking of the Black, Muskegon and Grand Rivers. However, natural reproduction is possible. A current cooperative multi-state tagging program should clarify the origin of coho in the vicinity of the Campbell Plant (M. Patriarche, personal communication).

When coho are approximately 100 mm, they move offshore following the thermocline (Phillips 1977). In the present study, no coho were captured during July and August but in September and November eight coho (140-421 mm, 126-825 g) were captured in offshore bottom gill nets at depths of 3, 6, 9 and 12 m. Capture sites and dates show evidence of the characteristic movement of this species: inshore activity during early spring to early summer, offshore movement following the thermocline as summer progresses and return to inshore water in the fall as the thermocline disintegrates (Engel and Magnuson 1971).

Movement of salmon seems to be correlated with temperature. Adult coho preferred a water temperature of about 11.6 C (Tody 1973). Edsall et al. (1974) found that peak rate of food conversion occurred at 12 C for coho, although highest growth rate occurred at 15 C. In this study, smallest coho (mean length 97 mm) were captured at 13 C water temperatures, while the majority of coho (mean length 129 mm) were captured at 10.6 C. The largest coho (mean length 198 mm) were captured in 9 C range. In comparison, during 1974 near the Cook Plant (Jude et al. 1978), smallest coho (70-90 mm) were caught at warmer water temperatures (23 C) near the upper lethal limit (25.1 C) (Brett 1952). Yearlings (100-170 mm) were captured at temperatures between 11-17 C while larger fish were taken from water temperatures of 11 C or less. Their data showed small fish inhabited warmer inshore waters during early summer, while larger fish inhabited cooler offshore waters. Night captures predominated near both the Cook Plant and the Campbell Plant.

Tadpole Madtom--

The tadpole madtom is distributed throughout the Lake Michigan basin except for its extreme northern portions (Becker 1976). Tadpole madtoms inhabit slow moving streams and shallow areas of lakes with soft, muddy bottom and abundant aquatic vegetation (Scott and Crossman 1973).

All 55 tadpole madtoms were seined in Pigeon Lake (Appendix 4). Pigeon Lake beach station T (influenced by the Pigeon River) and V (undisturbed Pigeon Lake), both similar to the typical habitat of tadpole madtom, were more productive than beach station S (influenced by Lake Michigan) contributing respectively 36 and 17 specimens. Only two madtoms were seined at station S. This species made up approximately 0.27% of our Pigeon Lake catch. Like young bullheads, tadpole madtoms

were never taken in bottom gill nets.

The tadpole madtom was represented in all monthly samples during the summer and fall (Appendix 4). We lacked sufficient gonad data (Table 48) to determine spawning time for this species. Tadpole madtoms were reported to spawn during May in Wisconsin (Becker 1976), July in Illinois and Iowa (Carlander 1969) and late June or early July in Canada (Scott and Crossman 1973). Our samples included only seven mature fish from 74 to 89 mm in total length, all of which had poorly or moderately developed gonads. Among the 44 immature tadpole madtoms collected, those caught in June and July (40-68 mm) were on the average larger than those caught in August, September, October and November (size range 29-58 mm). Comparison with the age-length data reported by Carlander (1969), suggested that the first group was composed of yearlings while the second group was mostly YOY.

The madtom is known to be active nocturnally and to seek cover such as holes under logs or empty cans during the day (Scott and Crossman 1973). In our study more fish were caught at night (35), but an appreciable number (20) were collected during the day.

Water temperatures at the time of capture ranged from 8.0 to 23.9 C; most tadpole madtoms were caught between 10 and 19 C. Although tadpole madtoms were reported to be eaten by larger fishes (Scott and Crossmann 1973), they have not been found in stomachs of predatory fish examined in our study.

Slimy Sculpin--

Aside from occasional use as bait by trout fishermen (Dymond 1926) the slimy sculpin is a little known species common to Lake Michigan (Becker 1976). Slimy sculpins in Lake Michigan are reported to occupy the nearshore habitat to a depth of approximately 90 m (Deason 1939). Spawning of this species is typical of the genus Cottus. Eggs are deposited on the undersurfaces of rocks, logs or other structures and fertilized by the male who then guards the nest (Koster 1936). Temperature at time of spawning for this sculpin was reported as 5-10 C from different localities in New York (Koster 1936) and 8 C in the Montreal River (Van Vliet 1964). Spawning occurred in Lake Michigan before early May in 1964 (Rottiers 1965); however, no temperatures were given. A monthly summary of gonad conditions for slimy sculpins caught in the present study (Table 49) showed that a few sculpins caught in June and 22 caught in December had moderate to well developed gonads. However, our collections were taken after the spawning season of this species, so exact time of spawning in the area of the Campbell Plant can not be confirmed using 1977 data.

Most slimy sculpins from Lake Michigan reached sexual maturity at

TABLE 48. Monthly gonad conditions of tadpole madtoms caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development				2	1		
	Mod. development				1			
	Well developed							
	Ripe-running							
	Spent							
Females	Slight development							
	Mod. development	1				2		
	Well developed							
	Ripe-running							
	Spent							
	Absorbing							
Immature		8	10	1	9	4	12	
Unable to distinguish		1			2	1		

TABLE 49. Monthly gonad conditions of slimy sculpins caught in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development							
	Mod. development	1				1		7
	Well developed							9
	Ripe-running							
	Spent							
Females	Slight development							
	Mod. development	1				2		2
	Well developed	1						4
	Ripe-running							
	Spent							
	Absorbing							
Immature		5	5					
Unable to distinguish		4					1	1

age III (Rottiers 1965). Rottiers also noted that all fish shorter than 55 mm were immature; whereas, all fish longer than 70 mm were mature. This agreed well with results of the present study which found all fish longer than 66 mm mature.

Out of 53 slimy sculpins caught in the present study, 44 were trawled from Lake Michigan. The remaining nine specimens were all seined at Pigeon Lake beach station S (influenced by Lake Michigan). It is apparent from our data that slimy sculpin preferred the Lake Michigan habitat, since none were caught at other stations in Pigeon Lake.

Apparently this species remains offshore in deeper water during summer and fall months. Six slimy sculpins were caught at depths of 15 to 21 m during June and July and two were caught at 15 m between October and December; none were caught at depths exceeding 15 m.

Most slimy sculpins caught in trawls (40 out of 44) were taken at water temperatures less than 7 C. This value closely agreed with the reported preference of 6 C for this species (Rottiers 1965). Wells (1968) noted that trawled slimy sculpins from Lake Michigan were most frequently caught in water that was 4-5 C. Temperatures at time of capture of specimens seined at Pigeon Lake beach station S ranged from 11.0 to 21.8 C. Only two sculpins there were taken at water temperatures exceeding 11.2 C. Symons et al. (1975) indicated that in laboratory studies individual sculpins varied widely in their choice of water temperature, although none preferred the extremes (3 or 21 C).

A monthly summary of catch by size group and diel period (Appendix 4) showed that there was a tendency to catch smaller sculpins in June - July compared with October - December. Absence of sculpins from Lake Michigan samples in August and September may be indicative of an offshore movement during these months with subsequent return of larger (mature) specimens to the area in October - December, followed by return of smaller sculpins in early spring and summer.

The nocturnal behavior of this species suggested by Jude et al. (1975) and Hubbs and Lagler (1964) concurred with observations of the present study. Forty-three of the 53 slimy sculpins caught in the area of the Campbell Plant were taken at night.

Slimy sculpin in the area of the Campbell Plant are undoubtedly an important food for sport fish, particularly brown trout and lake trout for at least part of the year. One lake trout examined from this area contained 17 slimy sculpins. In addition many brown trout caught in the area (30) had eaten slimy sculpins.

We expect the slimy sculpin will behave in a fashion similar to that observed at the Cook Plant, where after installation of intake and

discharge riprap, they colonized the area and developed large populations. Many adults were impinged and larvae were entrained. The same pattern is expected for the future offshore intake and discharge structures at Campbell if a similar apron of riprap is used for the structures.

Grass Pickerel --

A close relative of the northern pike, the grass pickerel, is a common resident of the quiet, weedy waters of the lower half of the Lake Michigan drainage basin (Becker 1976). This species is a smaller member of the pike family with a maximum reported size in the United States of 381 mm, 397 grams (Trautman 1957). Due to its size, the grass pickerel has little importance as a sport fish, and no importance commercially. Grass pickerel are known to hybridize in nature with northern pike, producing infertile offspring (Scott and Crossman 1973).

Spawning usually occurs during April in Ontario (Crossman 1962) and Wisconsin (Kleinert and Mraz 1966), but there is evidence of low intensity fall spawning (Scott and Crossman 1973). No fish collected in the present study during late summer or early fall exhibited the advanced state of gonad development which necessarily preceeds spawning (Table 50). This leads us to believe that spring spawning was more likely in our area. Grass pickerel build no nests, but rather abandon their eggs after spawning (Scott and Crossman 1973). These authors report that the eggs are demersal and slightly adhesive. Sexual maturity in grass pickerel occurred at a minimum of 157 mm in males and 141 mm in females in Jones Creek, Ontario (Crossman 1962). Our data suggest similar length-at-maturity values. Specimens captured ranged in length from 70 to 290 mm (Appendix 4).

The grass pickerel is a fairly common inhabitant of Pigeon Lake, being recorded from all months in which seining was performed. Most (14) were collected in August. There is an apparent preference for shallow nearshore habitat as 48 of the 50 grass pickerel were seined in areas of gradual slope, stations T (influenced by Pigeon River) and V (undisturbed Pigeon Lake). Only one grass pickerel was seined at station S (influenced by Lake Michigan), which has a steep slope, and one was gillnetted at station Y (influenced by Pigeon River). No apparent preference for either diurnal or nocturnal activity was noted (Appendix 4). None were taken in Lake Michigan.

Catch temperature ranged from 8.0 to 26.5 C. Preferred temperature of grass pickerel is reported to be 25.5 C (Crossman 1962), indicating that this species is tolerant of relatively high temperatures.

Grass pickerel in Pigeon Lake function ecologically as both predator and prey. Grass pickerel have been found in the stomachs of

TABLE 50. Monthly gonad conditions of grass pickerel caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development		3	4	1	2	1	
	Mod. development				2	1	2	
	Well developed							
	Ripe-running							
	Spent							
Females	Slight development	2	1	2		2	1	
	Mod. development		1		1	1	2	
	Well developed							
	Ripe-running							
	Spent				1			
	Absorbing				1			
Immature		1	4	6	1			
Unable to distinguish		1		2			1	

northern pike. In turn, grass pickerel stomachs have contained yellow perch, lake chubsucker, bluntnose minnow and golden shiners. The habitat of Pigeon Lake, as well as the abundant food supply is highly conducive to the survival and propagation of this species.

Brown Trout--

Brown trout were first introduced to Lake Michigan in 1883 (Brynildson et al. 1973). Natural reproduction, occurring both in the lake and in inflowing streams and subsequent plantings of several hundred thousand fish have resulted in the firm establishment of this species in the Lake Michigan basin (Becker 1976). Little has been written on brown trout habitat requirements in lake environments, but in streams, this species is more tolerant of warmer waters and lower oxygen levels than the brook trout, and as such is able to survive in relatively marginal habitats (Becker 1976). Movements of brown trout can be fairly extensive. One year after being planted in Lake Michigan, some specimens were found up to 323 km from the point at which they had been released, though most of the recovered fish were found less than 24 km away (Becker 1976).

A total of 49 brown trout were captured from June to November in Lake Michigan during this study; none were ever collected from Pigeon

TABLE 51. Monthly gonad conditions of brown trout caught in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development	1	2	1	3		7	
	Mod. development		1		3			
	Well developed				2		5	
	Ripe-running							
	Spent							
Females	Slight development	1	1	1	4			
	Mod. development	1		1				
	Well developed		1		1		1	
	Ripe-running						1	
	Spent							
	Absorbing							
Immature		4						
Unable to distinguish		4			1			

Lake (Appendix 4). Most fish were collected during September (15), November (14) and June (11). Thirty-nine of the fish (measuring 200 to 680 mm) were caught by gill net and ten (mostly between 130 and 200 mm) were collected by seine. Seventy-seven percent of the fish were caught at night, which concurred with Brynildson et al. (1973) who noted peak periods of activity for brown trout occurred during the evening, night and early morning. All but three brown trout were taken in water 6 m deep or less. Similar numbers of brown trout (10-14 per station) were captured at 1.5, 3 and 6 m. Our gonad development data (Table 51) suggested that spawning took place from the latter part of September to November, which is consistent with the findings of Jude et al. (1975), Scott and Crossman (1973) and Becker (1976). Spawning generally occurs in water temperatures of 6.7 to 8.9 C (Scott and Crossman 1973) and seems to be induced by the shortening periods of daylight during fall (Brynildson et al. 1973).

Approximately 60% of the brown trout captured had food in their stomachs. Fish were found most often in the stomachs of larger (greater than 600 mm) specimens. One 668 mm individual had ingested 12 alewives averaging 35 mm in length. In fact, during June - December 1977 alewives were the only recognizable fish found in brown trout stomachs. During April 1978 however, slimy sculpins predominated the diet, while rainbow smelt were also found in some stomachs. Brynildson et al.

(1973) reported that the diet of brown trout larger than 228 mm was composed largely (up to 70%) of fish.

The number of seined brown trout less than 254 mm increased with increasing water temperature at Lake Michigan beach stations during June; at stations Q (8.0 C), P (9.5 C) and R (10.6 C), zero, one and six brown trout respectively were caught. In a comparable 1973 study of Lake Michigan near the Cook Plant by Jude et al. (1975), brown trout were found most frequently at water temperatures from 6 to 16 C, which coincided closely with our findings where most brown trout were caught in 7 to 13 C waters.

The brown trout is one of the more wary game fish, and as such is challenging to catch. Thus, because of its good growth (up to 242 mm/yr, Becker 1976) and excellent eating quality, brown trout are a popular species among Lake Michigan anglers.

Lake Chubsucker--

The lake chubsucker is a common species in the southern half of lower Michigan where it occurs in lakes, ponds, rivers and quieter streams (Becker 1976). This species is apparently near the northernmost limit of its range in Michigan. Although this species is of little or no direct importance as a commercial or sport fish, it undoubtedly serves as a forage species and has been observed in the stomachs of both northern pike and grass pickerel in Pigeon Lake. A small resident population of lake chubsuckers, does exist in Pigeon Lake.

All 46 lake chubsuckers (50-210 mm) in the present study were seined at beach stations in Pigeon Lake (Appendix 4). Most (18) were collected in June. The capture of 43 chubsuckers at station T (influenced by Pigeon River) suggested a preference by this species for a more riverine habitat. Of the three remaining chubsuckers, two were caught at station S (influenced by Lake Michigan) and one was caught at station V (undisturbed Pigeon Lake). Water temperature range at time of capture was 8.0-23.4 C. Most lake chubsuckers were 45-95 mm (about 2 yr old, Carlander 1969), but some larger fish up to 210 mm were also captured (Appendix 4). Age growth data summarized by Carlander (1969) indicated extreme variability in growth of this species.

Spawning occurs from May to June. Whether this species spawned in Pigeon Lake or in the further reaches of the Pigeon River is unknown. Due to rapid deterioration after death, the sex and gonad conditions of most lake chubsuckers were difficult to distinguish. Hence we have no clues as to spawning time or location in Pigeon Lake.

Longnose Sucker --

The longnose sucker is restricted to the northern portion of North America, Lake Michigan being the southern edge of its range (Becker 1976). Although this species sometimes occurs in large numbers, its contribution to the commercial catch of all sucker species in the Great Lakes is low (Bailey 1969).

Thirty-six longnose suckers were collected, all from Lake Michigan; 16 in July, 13 in August, 6 in September and 1 in November (Appendix 4). This species appeared to be relatively uncommon near the Campbell plant, compared to other areas in Lake Michigan. Jude et al. (1975), with greater fishing effort, collected 85 specimens in 1973 in the vicinity of the Cook Plant (southeastern Lake Michigan).

With the exception of one specimen trawled in November, all longnose suckers were caught in gill nets, 23 at night and 12 during the day. Of the gillnetted specimens all were caught in bottom gill nets except one taken in a surface net set in July. Of the 23 fish collected in gill nets at night, 4 were caught between the 9 and 12 m depths, 19 between 3 and 6 m and 1 at 1.5 m. All day catches were made at the 6 m contour. Although large numbers of longnose suckers were found at greater depths in other areas (Harris 1962, Jude et al. 1975, Liston and Tack 1975), they seemed to prefer the 3-6 m contours near the Campbell Plant. These data also indicated that longnose suckers tended to be more active and occupied a wider inshore area at night than during the day.

Longnose suckers probably seldom enter Pigeon Lake as none were collected there and only one was reported impinged at the Campbell Plant during the period January 1974 - March 1975 (Consumers Power Company 1975). However, adults may use the Pigeon River for spawning in spring.

Longnose suckers collected ranged in size from 249 to 570 mm in total length, the majority being large individuals (Appendix 4). This species was reported to spawn in spring in streams or shallow areas of lakes when streams were not available (Scott and Crossman 1973). Near the Cook Plant, southeastern Lake Michigan spawning probably took place in late March, April or May (Jude et al. 1975). In 1977, our study started after the reported spawning season of longnose sucker and gonad condition data from 1977 (Table 52) were inconclusive. Preliminary observations of gonad conditions of fish caught in spring 1978 indicated that longnose suckers spawned in early April or May. The low catch of longnose suckers in April 1978 (only one specimen collected) suggested that spawning occurred outside the study area. As the longnose sucker normally spawns in streams, it was suspected that it may utilize Pigeon River as a spawning ground. No longnose suckers, however, were collected in Pigeon Lake in this study.

TABLE 52. Monthly gonad conditions of longnose suckers caught in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development							
	Mod. development		4				1	
	Well developed		3	3	3			
	Ripe-running							
	Spent							
Females	Slight development							
	Mod. development		1	1				
	Well developed		1	2	3			
	Ripe-running							
	Spent							
	Absorbing							
Immature								
Unable to distinguish				1				

The longnose sucker is a cold water species. Only one individual was caught at water temperatures above 15 C. The majority were collected between 7 and 12 C.

Yellow Bullhead--

The yellow bullhead is widely distributed throughout the Lake Michigan basin (Becker 1976). It usually occurs in slow-moving streams, shallow bays of lakes and in ponds with abundant aquatic vegetation (Trautman 1957). This species has little commercial importance and comprised only a small fraction of the total catch of all bullhead species in the United States (Scott and Crossman 1973).

In the vicinity of the Campbell Plant, yellow bullheads are probably restricted to Pigeon Lake as none were caught in Lake Michigan. The 35 specimens collected made up approximately 0.17% of the total Pigeon Lake catch (Table 14 and Appendix 4). Yellow bullheads appeared to be less abundant than one of its interspecific competitors, the brown bullhead, of which 120 were observed in our collections.

Eighteen of the yellow bullheads collected were YOY from 19 to 61 mm in total length (Appendix 4). All were captured by seine: 11 at Pigeon Lake beach station V (undisturbed Pigeon Lake), 6 at Pigeon Lake

beach station T (influenced by Pigeon River) and 1 at Pigeon Lake beach station S (influenced by Lake Michigan). Of the remaining 17 fish which ranged from 94 to 421 mm (Appendix 4), 11 were gillnetted at Pigeon Lake openwater station M (influenced by Lake Michigan) and 6 were seined at the three beach stations in Pigeon Lake (S, T and V). These data indicated that YOY yellow bullheads avoided areas influenced by Lake Michigan, while larger individuals seemed to occupy several types of habitat in Pigeon Lake.

The nocturnal activity (including feeding) of yellow bullheads reported by Scott and Crossman (1973) was also observed in this study. With the exception of one individual, all specimens were collected after dark (Appendix 4).

Yellow bullheads spawn in May and June in Illinois (Carlander 1969). The male guards the nest and the brood of young until they are approximately 51 mm in length (Scott and Crossman 1973). Gonad data from our study (Table 53) suggested that spawning of yellow bullhead in Pigeon Lake also occurred in May or early June.

Yellow bullheads were caught every month during the sampling period except September (Appendix 4). Relatively large number of adults were collected in October (10 of 18). Young-of-year, with an average size of 36 mm, first appeared in August samples. Catches of YOY declined substantially in October and November as YOY grew to larger sizes (Appendix 4). Reasons for the complete absence of adult and YOY yellow bullheads from our September collections are not known.

Water temperatures recorded at time of capture for yellow bullheads varied from 8.0 to 23.0 C. The majority of adults were caught at 8.0 C and no large individual was taken in water warmer than 19.2 C. Most young yellow bullheads were caught at water temperatures around 23 C in August and 8 C in October.

Carp--

Carp were first introduced to North America as a food resource in 1877 (Johnsen and Heitz 1975) and were first stocked in Michigan waters in 1880 (McCrimmon 1968). Habitat requirements for this species include shallow marshy areas where feeding and spawning take place, and deeper waters to retreat to during colder months (McCrimmon 1968). The carp's highly tolerant, adaptive and prolific nature has allowed it to successfully occupy and sometimes dominate a wide range of aquatic habitats (McCrimmon 1968).

In this study, 15 carp were captured in Pigeon Lake (three in July) while seven were caught in Lake Michigan (four in July) (Appendix 4). All but one carp were caught at night. Carp are generally most active

TABLE 53. Monthly gonad conditions of yellow bullheads caught in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, during 1977. All fish examined in a month were included except poorly received specimens.

	Gonad condition	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males	Slight development	1		1		3		
	Mod. development							
	Well developed						1	
	Ripe-running							
	Spent							
Females	Slight development		1			3		
	Mod. development	1				2	1	
	Well developed							
	Ripe-running							
	Spent	1				1		
	Absorbing							
Immature				13		4	1	
Unable to distinguish				1				

at night and spend days in shallow protected bays (Johnsen and Heitz 1975). In the present study 13 carp were collected in gill nets set along shorelines in water 6 m deep or less, while nine were captured in seines. Water temperatures at the time of capture ranged from 2.4 to 23.0 C. The entire sample of carp, consisted of ten males, eleven females, and one immature; length range was 32 to 768 mm.

Of the 22 carp captured, 14 had ripe gonads and some of these fish occurred in each sampling month from late July to early December. Carp spawning is triggered mainly by water temperatures, and is most prominent between 15 and 26 C in May and June, but extended spawning may occur intermittently through the summer and early fall depending on water temperatures (McCrimmon 1968). Adhesive eggs are laid on aquatic vegetation in shallow water less than 1.2 m deep (Jester 1974).

In Lake Michigan, carp were only found in nearshore waters. Three carp were seined at beach station Q (s. discharge), two at station P (s. reference) and two were caught in bottom gill nets at nearshore stations A (1.5 m - s.) and B (3 m - s.). In Pigeon Lake eight of the 15 carp collected were caught in gill nets at station M (influenced by Lake Michigan); the size range (516-768 mm) of these carp (Appendix 4) was similar to those caught in Lake Michigan (515-758 mm). Of the remaining carp caught in Pigeon Lake, three (527-591 mm) were gillnetted at

openwater station Y (influenced by Pigeon River), two (32 and 203 mm) were seined at station T (influenced by Pigeon River) and two (405 and 407 mm) were seined at station V (undisturbed Pigeon Lake).

Carp are generally not popular as either a food or a sport fish. They are accused of disrupting aquatic environments with their feeding behavior, and of crowding out other more desirable species of fish. However, carp are sought by some with hook and line, spear and bow and arrow, and carp meat products are becoming increasingly acceptable (Becker 1976).

Black Bullhead--

The black bullhead is widespread in the freshwaters of North America (Scott and Crossman 1973). In Michigan it is commonly found in lakes, warm streams and rivers. This species has limited commercial importance, but has significant value in the sport fishery of Wisconsin (Becker 1976).

All of the 17 black bullheads from the present study were captured in Pigeon Lake (Appendix 4). Presence of eleven YOY black bullheads seined between August - November 1977 suggested that Pigeon Lake was utilized as a nursery area. YOY were captured during day and night sampling and ranged in size from 49 mm (1.7 g) to 91 mm (9.6 g). Temperature range at time of capture was 10.9 - 17.8 C.

In agreement with findings by Darnell and Meierotto (1965) indicating nocturnal activity of large black bullheads, all large specimens in the present study were also caught at night. Large black bullheads ranged in size from 289 mm (365 g) - 321 mm (590 g). All adult bullheads were caught in gill nets, except one which was seined; temperature range at time of capture was 15.0 - 21.0 C. Black bullheads were fairly common in past impingement samples, with 43 impinged between January 1974 and March 1975 (Consumers Power Company 1975). Black bullheads are usually not present in areas where brown or yellow bullheads live (Scott and Crossman 1973). This may help explain their low abundance in Pigeon Lake since 134 brown bullheads were caught there during the present study.

Silver Redhorse--

The silver redhorse is distributed throughout the central portion of the Lake Michigan basin (Becker 1976). It has little recreational or commercial importance except for an undetermined quantity caught and marketed with other species as suckers (Scott and Crossman 1973). In Iowa spawning takes place in streams in April and May when water temperature reaches 13.3 C (Becker 1976).

This species was apparently uncommon near the Campbell Plant. Of the 11 silver redhorse collected, one was an immature individual 57 mm and the others were adults (seven males and three females) ranging in size from 486 to 595 mm. The majority of these fish had moderate or well-developed gonads. All specimens were caught in Lake Michigan (six in July, two in August, three in September and one in November), at water temperatures between 8.2 and 21.5 C. Four were seined at night at beach station R (n. discharge) and seven were gillnetted both during the day and at night at reference stations A (1.5 m - s.) and B (3 m - s.).

The 1977 sampling program started after the reported spawning season of silver redhorse, so we are not able to determine if this species uses the Pigeon Lake-Pigeon River system for a spawning ground.

Lake Whitefish--

The lake whitefish occurs commonly in the nearshore waters of Lake Michigan (Becker 1976). It is a cold-water species which descends into the cooler water of the hypolimnion during summer months over most of the southern part of its range (Scott and Crossman 1973).

Eleven lake whitefish were captured in the course of this study, all during night sampling. All but one of the fish were caught during June and July in cold water temperatures ranging from 6.0 to 8.2 C. Nine of the fish were trawled at stations 6, 12 and 15 m deep, and two were gillnetted at a depth of 6 m. Fish ranged in size from 261 to 466 mm (Appendix 4). Most lake whitefish are mature at 360 mm (Machniak 1975).

Spawning for this species normally takes place in November and December at depths less than 7.6 m (Scott and Crossman 1973). Lake whitefish spawn randomly (no nest construction) over sand or stone bottoms (Becker 1976) in areas where wave action and water currents keep the spawning site free of silt (Machniak 1975). The fact that no lake whitefish were observed during the fall months of this study may have been due to lack of optimum temperatures during the times of our field sampling. Water temperatures were 10.5 to 12.3 C during October and November, then dropped to 0-1.5 C in December at the stations where lake whitefish had been captured during the summer. Spawning is normally delayed until water temperatures drop to approximately 7.8 C (Lawler 1965).

Lake whitefish are exploited commercially and have been a valuable food fish in the Great Lakes. Their numbers have declined in the last 125 years due principally to over-exploitation and degradation of the environment (Wells and McLain 1973).

Rainbow Trout--

The rainbow trout is native only to the west coast of North America, but has been successfully introduced to many other parts of the world (Scott and Crossman 1973). Rainbows were first planted in Lake Michigan in 1880 (Smiley 1881, cited in MacCrimmon and Gots 1972) where it became established via further plantings and natural spawning in several Michigan streams (McCrimmon and Gots 1972). Spawning was impaired somewhat in the early 1900's by the construction of hydro-dams on major spawning streams.

In the 1940's and early 1950's, sea lamprey predation caused a serious decline in rainbow trout populations, since lampreys were selective for the largest members (hence the largest potential spawners) of the population (Borgeson 1974). Chemical control of lamprey, some dam removal and fish ladder construction, as well as increased plantings of rainbows, have replenished the population.

Of the ten rainbow trout caught in the present study (300-587 mm), eight were taken from Lake Michigan and two from Pigeon Lake (Appendix 4). All rainbows were collected between late September and November, and eight contained ripe sex products. The gonad of one 581 mm male was found in the ripe-running condition in Pigeon Lake in early November. This species mainly spawns between January and March but a less pronounced fall spawning run occurs (Becker 1976). Rainbow trout spawn in gravel bottom streams with temperatures from 10 to 15.5 C (Scott and Crossman 1973). Temperatures in the lakes when specimens we caught were taken ranged from 10.5 to 12.9 C. Rainbows may spawn three or four times before dying (Becker 1976).

All but one of the fish were caught at night. Six fish were caught in gill nets set at 3 and 6 m and four fish were seined.

Rainbow trout in Lake Michigan ate mostly alewives leading to average growth of 76 mm/yr over the first 3 yrs (Stauffer 1972). Becker (1976) recorded growth from 113 g to 7.3 kg in 5 yrs. Rainbow trout are very popular among sport fishermen, both for their fine flesh and fighting ability.

Round Whitefish--

Round whitefish are distributed in North America southward from rivers and lakes near the Arctic Ocean to the lakes of the St. Lawrence-Hudson Bay drainage basins and all the Great Lakes except Lake Erie (Armstrong et al. 1977). In Lake Michigan, round whitefish are found in decreasing numbers from north to south as water temperatures become warmer, and are found only occasionally in the more southern portions of the lake (Armstrong et al. 1977).

In this study, eight round whitefish were collected, in July (1) and from September through December (7). All were collected from Lake Michigan in water depths of 3-9 m. These fish, ranging from 141 to 182 mm in length (Appendix 4), were caught by gill nets (6) and trawls (2) in equal numbers during the day and night. Three individuals captured in the latter part of September had well developed gonads. Spawning usually occurs before mid-December when fish have reached age 3 (Mraz 1964). One round whitefish was caught in 1 C water in December, and during other months sampled, specimens were found in water with temperatures of 6.6 to 11.0 C. Round whitefish are highly esteemed as a food fish and are commercially valuable though they are not found in great abundance anywhere over their range.

Channel Catfish--

The channel catfish is native to streams and lakes of eastern United States and southern Canada and has been widely introduced in the western states. It is an important sport species throughout its range and is exploited commercially in Lake St. Clair, Lake Erie and the Mississippi River (Scott and Crossman 1973). There is, however, no commercial catch in Lake Michigan (Becker 1976). This species adapts readily to pond conditions and is now the most commonly raised food fish in warm-water ponds in the United States (Bardach et al. 1972).

Six adult channel catfish (five males and one female) ranging in size from 337 to 663 mm (Appendix 4) were caught in bottom gill nets at 3 to 9 m stations in Lake Michigan, all during the August sampling period. One YOY (58 mm in total length) was seined in November at Pigeon Lake beach station S (influenced by Lake Michigan). All channel catfish were caught at night, confirming the nocturnal feeding activity of this species noted by Finke (1964). Water temperatures at fishing time were between 18.5 and 20.5 C. Although our data seem to indicate that channel catfish preferred the Lake Michigan habitat, movement of this species into Pigeon Lake was established by the occurrence of 161 channel catfish in impingement samples collected between January 1974 and March 1975 (Consumers Power Company 1975).

Warmouth--

The warmouth is a centrarchid common to many of the lakes and rivers bordering eastern Lake Michigan, particularly those south of the White River (Becker 1976). Lower Michigan appears to be near the northern limit of its range (Larimore 1957). Although this species is of no commercial importance, it is caught in the Lake Michigan drainage basin by sport fishermen along with the other sunfishes. The habitat available in Pigeon Lake is particularly suited for the warmouth due to abundant growth of aquatic vegetation and a soft, debris-covered bottom

which this species prefers (Hubbs and Lagler 1964). Five of the six warmouth (four males and one female) in the present study were caught from June-September at beach seining stations S, V and T in Pigeon Lake. One female warmouth was caught in September in a gill net at openwater station Y, Pigeon Lake. Specimens ranged in size from 154 mm (72.4 g) to 192 mm (150.2 g) (Appendix 4). Water temperature at time of capture ranged from 11.5 to 19.0 C. Warmouth appeared to have a small resident population in Pigeon Lake.

Smallmouth Bass--

Smallmouth bass, originally restricted to east-central North America, now occur everywhere in the United States following extensive introductions which began in the mid 1800's (Scott and Crossman 1973). It is a prized sport fish throughout its range and an excellent food fish (Becker 1976). Spawning takes place from late May to early July in nests built on sandy, gravelly or rocky bottoms usually near the protection of rocks or logs (Scott and Crossman 1973).

Five smallmouth bass ranging in size from 165 to 435 mm were collected in this study (Appendix 4). Of these, three were seined during the day; two at Pigeon Lake beach station T (influenced by Pigeon River), one at Pigeon Lake beach station V (undisturbed Pigeon Lake). The remaining two were gillnetted during the day at Pigeon Lake openwater station M (influenced by Lake Michigan). Water temperatures at fishing time were between 11.1 and 16.6 C. Two males, one with moderate and the other with little gonad development and one female with slight gonad development were caught in June. The other two, caught in November, were released and therefore not examined. Although our catch in 1977 was relatively low, smallmouth bass appeared to be a common species near the Campbell Plant as a total of 156 individuals were found in weekly impingement samples during the period January 1974 - March 1975 (Consumers Power Company 1975).

Mottled Sculpin--

The mottled sculpin is a common inhabitant of Lake Michigan (Becker 1976) where it reportedly occupies the nearshore areas and mouths of shallow tributaries (Deason 1939). Spawning activity of this species is similar to the slimy sculpin (See Slimy Sculpin). Temperature at time of spawning was reported as 10 C in New York (Koster 1936), 8.9-13.9 C in Wisconsin (Ludwig and Norden 1969) and 6-7 C in Maryland (Savage 1963).

Of the five mottled sculpins caught, four were trawled in June in Lake Michigan. Water temperature ranged from 4.5 to 6.1 C. The occurrence of this species at stations F (18 m) and G (21 m) indicates that this species may be less of a near shore inhabitant than suggested

by Deason (1939). One additional mottled sculpin was seined in November at Pigeon Lake beach station S at a water temperature of 11.0 C. The two largest specimens (80 and 94 m) were both males with little gonad development. The remaining three (38, 40 and 55 mm) were all immature (Appendix 4).

Due to the difficulties in distinguishing this species from the slimy sculpin (See METHODS-LABORATORY ANALYSIS OF JUVENILE AND ADULT FISH) the mottled sculpin in the vicinity of the Campbell Plant may be more abundant than indicated by our data. Mottled sculpins may serve as forage for some of the game species in the area, but the degree of importance is unknown.

Chinook Salmon--

The chinook salmon was the first Pacific salmon to undergo widespread introduction outside of its native range (Scott and Crossman 1973). This species was first stocked in Lake Michigan in 1967 and by the end of 1970, 4.1 million fingerlings had been released (Wells and McLain 1973). Chinook salmon usually spawn at age III or IV and die after spawning (Mercer Patriarche, personal communication, Institute for Fisheries Research, Michigan Department of Natural Resources, Ann Arbor, Michigan). Preliminary results of a study of chinook salmon indicate that some natural reproduction takes place in Michigan's trout mainstreams (L. Carl, personal communication, Institute for Fisheries Research, Michigan Department of Natural Resources, Ann Arbor, Michigan). Chinook reach a large size (10-20 kg) in the lake and their voracious feeding helps contain the prolific alewife population (Becker 1976).

In the present study, three adult and one immature chinook salmon were collected from Lake Michigan (Appendix 4). The immature fish, which measured 92 mm, was taken in a night seine haul performed in early June in 8.0 C water at beach station Q (s. discharge). The three adults were all captured in night surface gill nets set at 6 m stations C and L. One was an 818 mm male collected in September in 6.1 C water and the other two were a male and female (378 and 571 mm respectively) caught in November in 12.3 C water. The two largest fish had well developed gonads. Spawning time for chinook salmon varies according to how far upstream they migrate, but generally occurs in the fall (Becker 1976). Although no chinook salmon were collected during regular monthly sampling in Pigeon Lake, a large adult was taken during electrofishing on 5 October 1977 opposite Station T (influenced by Pigeon River). Apparently some chinook enter the Pigeon River area to spawn in the fall. Many chinook salmon were also observed in the discharge canal during autumn 1978.

Longnose Dace--

The longnose dace is widely distributed in north-central North America (Hubbs and Lagler 1964). It is often associated with gravel and boulder bottoms of fast flowing streams and inshore waters of large lakes (Scott and Crossman 1973). Jude et al. (1975) found the occurrence of longnose dace relatively constant for all months, in southeastern Lake Michigan near the Cook Plant. Longnose dace accounted for 0.02% (41 fish) of the total number of fish captured in their standard series fishing in 1973. Anderson and Brazo (1978) studied the distribution and feeding habits of longnose dace in the beach zone of Lake Michigan near Ludington.

In the present study four longnose dace (38-59 mm) were collected, all by seine (Appendix 4). Two dace came from Lake Michigan beach station P (s. reference) in October and November, one came from beach station R (n. discharge) in November and one came from Pigeon Lake beach station S (influenced by Lake Michigan) in September. The largest individual (59 mm caught at station P in October) was a male in an early stage of gonad development. All other specimens were immature. Longnose dace were caught in water temperatures of 11.2-17.0 C. Although Simon (1946) remarked that this species is of great value as a forage fish in Wyoming, its low abundance indicates little possibility of this in the area around the Campbell Plant.

Emerald Shiner--

The emerald shiner is a planktivorous open-water minnow (Flittner 1964) which, until the early 1960's was very abundant in Lake Michigan (Wells and McLain 1973). The sharp decline and near demise of emerald shiners in Lake Michigan noted by shoreline residents and bait dealers during this period was apparently linked to an increase in alewife abundance (Smith 1970). Emerald shiners were still "highly conspicuous" in the harbor at Grand Haven, Michigan in 1970 (Wells and McLain 1973), but our visual observations at Grand Haven during 1977 showed that only gizzard shad were present in large concentrations.

Emerald shiners were notably absent from the inshore waters of Lake Michigan in the vicinity of the Campbell Plant, with only one specimen caught during our August seining activities at beach station R (n. discharge). This finding corresponded well with a similar low occurrence of emerald shiners around the Cook Plant in southeastern Lake Michigan (Jude et al. 1975 and Jude et al. 1979). Three emerald shiners were caught in Pigeon Lake, indicating the possiblity of a small resident population there. These fish were seined at beach stations S and T during July to September. This species probably has little value as a forage species in the area. Emerald shiners were caught at temperatures from 17 to 24 C and ranged in size from 63 to 81 mm (Appendix 4).

Banded Killifish--

The banded killifish is common and widely distributed throughout the eastern shore of Lake Michigan and its tributaries (Becker 1976). It prefers quiet waters, and is usually found in small schools over sand, gravel or detritus-covered bottoms having patches of submerged vegetation (Scott and Crossman 1973). Only two banded killifish were captured in the present study. These specimens were caught by seine at Pigeon Lake beach station V (undisturbed Pigeon Lake) in November when water temperature was 12.6 C. The first was a female, 43 mm long while the second was a 40 mm male (Appendix 4). Although this species may serve as important food for game fish in areas where killifish are abundant (Scott and Crossman 1973), they are probably an unimportant forage species in Pigeon Lake because of their scarcity.

Goldfish--

The goldfish is an East Asian species widely introduced into all parts of the United States (Scott and Crossman 1973). Goldfish occur sporadically throughout the Great Lakes basin (Hubbs and Lagler 1964). This species prefers small, warm lakes and streams, but can survive in relatively cold water. Two YOY measuring 22 and 24 mm (Appendix 4) were caught in seines during August at Pigeon Lake beach station S (influenced by Lake Michigan) at a water temperature of 22.8 C. Apparently some reproduction of goldfish occurred in Pigeon Lake. A few adult goldfish were also sighted while electrofishing in the area. Goldfish appeared to be an uncommon species in the Campbell Plant vicinity.

Burbot--

The burbot is a common species in Lake Michigan (Becker 1976). Only two burbot were caught during the present study. One male (401 mm, 550 g) with well developed gonads was caught in a gill net at Pigeon Lake openwater station M (influenced by Lake Michigan) in early December 1977 (Appendix 4). Water temperature at time of capture was 2.5 C. In Lake Michigan, a female burbot (358 mm, 382.3 g) with well developed gonads was also captured during December at station D (9 m - s.) in a gill net. Water temperature at time of capture was 1.0 C. Occurrence of these burbot with well developed gonads along with the entrainment of a single burbot larvae in February 1978, suggested the possibility that Pigeon Lake or this vicinity of Lake Michigan may serve as a spawning area for burbot. Jude et al. (1975) also documented the inshore area in the vicinity of the Cook Plant, southeastern Lake Michigan as a spawning and nursery area for burbot. Movement of burbot into river mouths for spawning has been reported in Lake Simco, Ontario (McCrimmon and Devitt 1954). More winter collections would be necessary to establish whether Pigeon Lake is used extensively by burbot as a spawning area.

This species comes into inshore waters during the colder parts of the year and is not generally abundant in the area around the Campbell Plant. However one was impinged during June 1974 (Consumers Power Company 1975).

Shorthead Redhorse--

One male shorthead redhorse, (438 mm, 900 g), was caught in the area of the Campbell Plant (Appendix 4). This specimen was gillnetted at station A (1.5 m - s.) in Lake Michigan in August, at a water temperature of 12.5 C. Shorthead redhorse inhabit shallow, clear waters of lakes and rivers and are intolerant of heavy silt (Scott and Crossman 1973). They are uncommon to common in widely disjunct locales in the Lake Michigan basin (Becker 1976). Apparently shorthead redhorse were uncommon in the area around the Campbell Plant during 1977.

Lake Sturgeon--

The lake sturgeon has exhibited the most abrupt decline of any species in Lake Michigan (Wells and McLain 1973). A single lake sturgeon was seined in the study area at Lake Michigan station Q (s.discharge) at a water temperature of 20 C, confirming its scarcity in the area as reported by Becker (1976). The specimen collected was 584 mm (Appendix 4) and was returned to the water unharmed. Age-at-length estimates given by Scott and Crossman (1973) suggest that this sturgeon was approximately 9 yrs old. The lake sturgeon is currently listed as a threatened fish species (U.S. Dept. Interior 1973).

Golden Redhorse--

The golden redhorse is reportedly common to the lower two-thirds of lower Michigan (Becker 1976). This species is apparently better adapted to rivers, where they inhabit slower moving reaches, probably avoiding heavily weeded areas (Trautman 1957). The only golden redhorse caught in the present study was a male (465 mm, 120 g) gillnetted in October at station M (6 m) in Pigeon Lake (Appendix 4). Water temperature was 9.7 C. This species was scarce in the Pigeon Lake area of the Campbell Plant, possibly due to the dense vegetation.

Bigmouth Shiner--

Only one bigmouth shiner (63 mm) was collected in the present study (Appendix 4). This specimen (sex undetermined due to poor condition of fish) was seined at station V (undisturbed Pigeon Lake) during June at a water temperature of 13.5 C. This species is common in small to medium-sized streams, preferring sandy bottoms frequently interspersed with gravel (Becker 1976). Bigmouth shiners probably have limited value as a forage species in Pigeon Lake due to its sparsity.

Cisco--

Cisco or lake herring was an important commercial species in Lake Michigan during the period 1890-1908. The initial decline of catch after 1908 resulted mainly from heavy exploitation by commercial fishermen (Wells and McLain 1973). Population explosions of introduced rainbow smelt in the 1930's and of smelt and alewives in the 1950's, were believed to cause the drastic reduction in lake herring populations in Lake Michigan (Wells and McLain 1973, Smith 1970).

Cisco were rarely found at temperatures above 16.7-17.8 C or at dissolved oxygen concentrations below 3-4 ppm at the deeper limit of their distribution (Becker 1976). Spawning takes place in the fall, usually in shallow water over gravel or stone but may occur in water as deep as 9-12 m (Scott and Crossman 1973).

The only cisco collected in this study was caught in a gill net at Pigeon Lake openwater station M (influenced by Lake Michigan) in June when the water temperature was 11.2 C. Age-length data of cisco from the Great Lakes region (Carlander 1969) suggested that the 389 mm (425 g) female we caught was approximately 8 or more yrs old. This species is apparently rare in the inshore waters of southeastern Lake Michigan. Jude et al. (1975) caught only one adult specimen in 1973 in the vicinity of the Cook Plant, southeastern Lake Michigan .

Blacknose Shiner--

Blacknose shiners vary in abundance from common to uncommon throughout the Lake Michigan basin (Becker 1976). In the present study one specimen (63 mm) was captured during June by seining at Pigeon Lake beach station V (undisturbed Pigeon Lake) (Appendix 4). Water temperature at time of capture was 13.5 C. The clear, weedy habitat of Pigeon Lake, preferred by blacknose shiners (Scott and Crossman 1973) should provide a suitable environment for this species. Ten blacknose shiners were impinged at the Campbell Plant between January-May 1974 (Consumers Power Company 1975). Since no early spring sampling was done during the 1977 field season, 1978 field sampling during this time may show this species to be more abundant than indicated by 1977 data.

Pirate Perch--

Pirate perch is the only living species of the family Aphredoderidae; the remaining members of the family are known only from fossil records (Hubbs and Lagler 1964). Pirate perch are found in Michigan as far north as the Pere Marquette River system in Mason County (Becker 1976). The reported preferred habitat of soft muck bottoms covered with organic debris (Becker 1976) described Pigeon Lake beach station T (influenced by Pigeon River) where the only specimen recorded

from our study was seined. This 72 mm male was caught during October when water temperature was 8.0 C. One pirate perch was also observed while electroshocking near station T. Ecological importance of this species is not known. This species is not abundant in the Great Lakes region, where it is near the northernmost limit of its range (Hubbs and Lagler 1964).

Quillback--

Localized populations of quillbacks exist in Lake Michigan; the concentration nearest the Campbell Plant is reported to be in the Grand River, Michigan (Becker 1976). One male quillback (465 mm, 1325 g) was caught at 6 m station M (Pigeon Lake) by gill net during December at a water temperature of 3.2 C. Quillbacks live in habitats as varied as clear lakes and turbid rivers (Scott and Crossman 1973). Although only one quillback was captured, preliminary examination of 1978 impingement data suggested the possibility of a local population in Pigeon Lake; also, initial 1978 observations in the discharge canal indicated that some quillback also utilized this habitat.

Creek Chub--

The creek chub was observed during April 1978 in Pigeon Lake, but none were caught during 1977 sampling. Creek chubs are widely distributed in the Lake Michigan basin, but are more common in streams than rivers (Becker 1976).

Fathead Minnow--

Although no fathead minnows were captured during 1977 sampling, this species was observed during supplementary sampling near Pigeon Lake beach station S (influenced by Lake Michigan), when approximately five were collected in one seine haul during April 1978. Fathead minnows are reported to be common in the Lake Michigan watershed (Becker 1976).

Northern Hog Sucker--

One northern hog sucker was observed in April 1978 in a non-sampled lot of impinged fish. No northern hog suckers were caught during our 1977 sampling efforts. This species was apparently uncommon in the area of the Campbell plant. Northern hog suckers prefer clear parts of streams and rivers, especially in riffle areas where the bottom is gravelly (Becker 1976).

Logperch--

Logperch have been observed in impingement samples in 1977 (Zeitoun et al. 1978) and 1978 on two occasions. Although they have not been

collected during our lake sampling, there are some indications that this species remains just offshore in 1-1.3 m of water outside the seining zone (Scott and Crossman 1973). These authors noted that this offshore distribution often leads to the species being mistakenly called uncommon in an area. Logperch prefer those regions of lakes, streams or rivers with sand and gravel bottoms (Becker 1976).

White Crappie--

White crappie have been observed by Consumers Power Company personnel in impingement samples (Consumers Power Company 1975, Zeitoun et al. 1978), although no white crappie were caught during our 1977 sampling. A widely disjunct population of this species is distributed through the southern half of the Lake Michigan Basin (Becker 1976).

Walleye--

One walleye was observed during electrofishing operations in Pigeon Lake during 1977. Populations of walleye are scattered throughout the Lake Michigan basin where its status is uncommon to common (Becker 1976). It is apparently uncommon in the area of the Campbell Plant.

Gar--

Gars have been observed at various times throughout the 1977 sampling period. Most sightings have been at distances too great to allow positive species identification. One longnose gar was observed maintaining a fixed position in the discharge canal in October 1977. An additional sighting of a gar, which may have been a spotted gar, was made while pulling a gill net in Pigeon Lake in September. Data for 1977 suggest that gars are uncommon in the area of the Campbell Plant.

Chestnut Lamprey--

One chestnut lamprey was observed during initial spring impingement sampling 1978. This species is parasitic on fishes and is generally found in large rivers (Becker 1976). Becker reported that there are numerous records of chestnut lamprey from lower Michigan. Since most nets are ineffective for sampling lamprey, its status in the area of the Campbell Plant is unknown.

Sea Lamprey--

This species of lamprey was also observed in impingement sampling in 1977 (Zeitoun et al. 1978) and in the spring of 1978. It has been observed in the Pigeon River prior to our sighting, but this area is considered marginal for sea lamprey production (personal communication, Bob Mormon, U.S. Fish and Wildlife Service, Ludington, Michigan). The Pigeon River was treated only once for sea lamprey in October 1964.

Tiger Muskellunge--

The tiger muskellunge is the result of hybridization of the northern pike with the muskellunge. One specimen was observed in September 1977 near Pigeon Lake openwater station Y (influenced by Pigeon River) during electrofishing.

Freshwater Drum--

The freshwater drum is occasionally found in the lower portions of tributaries to Lake Michigan (Becker 1978). Although absent from standard sampling in 1977, drum were observed in the area of the Campbell Plant in 1978. One drum was caught in a bottom gill net at station L (6m - n.) in September 1978. An additional drum was caught by hook and line in August 1978 near station X (undisturbed Pigeon Lake).

Mark and Recapture

Largemouth bass ($\geq$ 220 mm) and northern pike were recaptured in large enough numbers to allow reliable estimates of population size in Pigeon Lake to be made. Northern pike were divided into two groups according to size, the smaller group being 177-300 mm, the larger being greater than 300 mm. Small largemouth bass (<220 mm), smallmouth bass and grass pickerel were marked, but insufficient recaptures prevented making a reliable population estimate.

An estimate of the population of northern pike ($\geq$300 mm) in Pigeon Lake was made based on four recapture periods during late September-December using the Schumacher/Eschmeyer Method (Ricker 1975). This method requires that the population remain constant throughout the sampling period. Fishing mortality by anglers was low and probably nonexistent. Few anglers were observed on the lake during this period and no fish were caught by anglers during our observations. Natural mortality for fish of this size is usually low so this factor was discounted. Our monthly sampling, responsible for 13 northern pike deaths, probably caused more mortality than that due to angling or natural causes, however, it is believed that fish killed during this period will not invalidate the population estimate.

During the mark and recapture experiments, 157 large northern pike ($\geq$300mm) were marked with individually numbered spaghetti tags. Total recaptures numbered 24 and only two fish were recaptured twice. Number of fish marked over the four periods varied from 18 in the December period to 49 in the November period (Table 54). Using the Schumacher/Eschmeyer equation, the estimated population within Pigeon Lake was 672 northern pike (95% confidence limits: 610, 749). This was felt to be a large population for a lake of this size.

Northern pike apparently moved around within Pigeon Lake rather than staying within a smaller home territory. Of the large northern pike recaptured, 63% were caught in a different area from that into which they were released, which provided good evidence that thorough mixing of marked individuals with the rest of the pike population had occurred.

The estimate for small northern pike (177-299 mm) was also based on four recapture periods. Again, fishing mortality can probably be discounted because of low fishing pressure and sublegal size. Natural mortality might have been higher than for larger pike, but was still probably insignificant. The smallest fish marked during the study was 177 mm and a fish this size should be beyond the point where high mortality would be significant. During the mark and recapture period 97 small pike were marked with fin clips. Of these fish, six were recaptured (Table 55). Using the Schumacher/Eschmeyer equation, the estimate for the number of small northern pike in Pigeon Lake was 628 with a 95% confidence interval of 589-670.

The population estimate for largemouth bass ($\geq$220 mm) also involved four recapture periods and no angling mortality was observed. Natural mortality was felt to be negligible. No largemouth bass of this size were caught in our sampling gear during the mark and recapture efforts, a good example of gear bias. Spaghetti tags were affixed to 147 largemouth bass during the study. Fourteen largemouth bass were recaptured, none of them twice. Results for each sampling period are presented in Table 56. The Schumacher/Eschmeyer equation yielded an estimate of 471 fish with 95% confidence limits of 349-724. There appears to be a large population of largemouth bass in Pigeon Lake.

Largemouth bass also appeared to move about within Pigeon Lake. Of the largemouth bass recaptured, 65% were caught in a different area than where they were released.

Largemouth bass under 220 mm total length were marked with a different fin clip during each period. Thirty-one were marked, but none were recaptured. Many more small largemouth bass were seen and not captured. The population of largemouth bass in this size range was very large, based on observations during electrofishing and from seine hauls. Marking sufficient numbers of fish to ensure recaptures would have taken too much time away from effort expended in capturing larger northern pike and bass. Therefore less time was spent dealing with small largemouth bass; consquently no estimate was made.

Seven smallmouth bass were marked during the period 21 September to 2 November 1977. Nearly all fish (265-459mm) were caught in November. No smallmouth bass were recaptured. The population of smallmouth bass appeared to be low based on our observations. During this experiment 42

TABLE 54. Population estimate data for northern pike ($\geq$300 mm) in Pigeon Lake near the J.H. Campbell Plant, fall, 1977. M_t = total number of marked fish at the start of the period, C_t = total number of fish captured during the period and R_t = number of fish recaptured during the period.

PERIOD (t)	DATE	M_t	C_t	R_t
I	9/21 - 9/28	0	47	0
II	10/5 - 10/6	47	47	5
III	10/18 - 10/20	89	47	7
IV	11/2 - 11/3	123	49	8
V	12/7	157	18	4

TABLE 55. Population estimate data for northern pike ($<$300 mm) in Pigeon Lake near the J.H. Campbell Plant, fall, 1977. M_t = total number of marked fish at the start of the period, C_t = total number of fish captured during the period and R_t = number of fish recaptured during the period.

PERIOD (t)	DATE	M_t	C_t	R_t
I	9/21 - 9/28	0	15	0
II	10/5 - 10/6	15	29	0
III	10/18 - 10/20	44	35	3
IV	11/2 - 11/3	67	30	3

TABLE 56. Population estimate data for largemouth bass ($\geqslant$220 mm TL) in Pigeon Lake near the J.H. Campbell Plant, fall, 1977. M_t = total number of marked fish at the start of the period, C_t = total number of fish captured during the period and R_t = number of fish recaptured during the period.

PERIOD (t)	DATE	M_t	C_t	R_t
I	9/21 - 9/28	0	24	0
II	10/5 - 10/6	24	48	1
III	10/18 - 10/20	71	36	2
IV	11/2 - 11/3	105	42	12

grass pickerel (105-282 mm) were marked. Grass pickerel were caught and marked throughout the study, but only one fish was recaptured. Grass pickerel seemed to be fairly abundant in Pigeon Lake based on our electroshocking results. The number of fish species observed while electroshocking in Pigeon Lake generally paralleled results from seining and gillnetting in Pigeon Lake. There were two species caught while electroshocking that were not captured with any other gear during sampling. A walleye (522 mm total length; 1700 g) was caught off the intake canal on 5 October 1977. A tiger muskellunge (263 mm total length; 75 g) was caught on 29 September near the upstream side of the bridge near Pigeon River. Both fish were marked and released.

FISH LARVAE AND ENTRAINMENT STUDY

Fish larvae are undoubtedly the most important life history stage of all fishes. Since the strength of year classes in adult fishes is ultimately controlled by the egg and larval stages, it becomes extremely important to understand the factors which affect the growth and survival of larval fish.

As of 1975, there were 45 power-generating plants on Lake Michigan which draw water from the lake for cooling purposes (Lake Michigan Federation 1975). It is common knowledge that most fish species use the inshore zone of the Great Lakes as a spawning ground and nursery area. Consequently, every power plant, domestic or industrial intake on the lake has the potential for entraining large numbers of fish larvae and eggs. Many larvae suffer severe stress and mortality.

The primary purpose of this part of the study was to gather enough data to determine what impacts were being made on fish larvae populations by the J. H. Campbell Power Plant's present and proposed cooling water system. The secondary objectives of this section included:

1) describe what species were present and in what abundances, as well as their spatial (vertical and horizontal) and temporal (seasonal and diel) distribution
2) determine which species utilized the Port Sheldon area as spawning and/or nursery grounds
3) gather information to correlate the appearance of fish larvae in field samples with occurrence in entrainment samples
4) completion of information about life cycles including spawning times and locations

Fish larvae were defined as any fish less than 25.4 mm in total length for simplicity in data manipulation. Periodically, fish greater than 25.4 mm were caught in net and sled tow samples. These fish were called fry for our purposes and analyzed separately from larvae. Larval fish data in this section were discussed by taxonomic group. Within a given species or group, seasonal distribution by month was discussed. A standard unit of concentration, no./1000 m^3, was used to compare densities at the various stations and times. Actual densities obtained were biased because of differences in efficiencies of the net in the diverse habitats sampled, with more and longer larvae captured at the more densely vegetated and turbid Pigeon Lake stations. More larvae were usually collected at night because of daytime net avoidance. These differences were taken into consideration when data were discussed. Another data compilation which we used to display differences in length of larvae collected from the various habitats was the length-frequency histogram. Many times we were able to separate from which lake entrained larvae were derived by examination of these histograms. These

data were also useful for determining growth relationships of the larvae in the two ecosystems.

Stations were established in Lake Michigan along two transects, which were identical to those used for adult fish (Fig. 1). One transect was in the area of the present onshore discharge (north transect) and one, the reference transect, was south of the plant. Sampling locations in the openwater of Pigeon Lake were also established (Fig. 2). Pre- and post-operational data comparisons were and will be made on the basis of these data. Beach stations were established in a similar manner for the above discussed comparisons as well as to determine the distribution and abundance of larval species at inshore stations. Sampling was also conducted in the intake canal to determine what fish larvae were present just prior to entry of water into Campbell's cooling-water system. Entrainment sampling, using the same 0.5 m diameter nets used in field collections, completed sampling the circuit that larvae were expected to travel.

Two types of gear were used to sample larval fish; regular plankton nets and a benthic sled-towing device (Fig. 5). These gear were able to sample the entire inshore aquatic habitat from surface waters to just off the bottom and from the beach zone out to 21 m (as far as we chose to go). These gear, which covered most areas of the physical habitat, combined with day and night sampling and more frequent collections during months of peak larval abundance, should provide a well-balanced understanding of the densities and distribution of fish larvae in the area of the Campbell Plant. A discussion of each taxonomic group (see Table 57 for a species list and our larval codes) follows.

Alewife

The most abundant species of larval fish in the area of the Campbell Plant was the alewife. Spawning of this species occurred in June-early August in southeastern Lake Michigan during 1973 (Jude et al. 1975) and in late June 1963 near Saugatuck (Allegan Co. Michigan - Edsall 1964). Studies on Lake Ontario suggested that actual time of spawning was temperature dependent (Pritchard 1929). Eggs are reportedly broadcast at random, demersal and essentially nonadhesive (Scott and Crossman 1973). Female alewives from Lake Michigan produced from 11,000 (from 160 mm fish) to 22,000 (192 mm fish) eggs (Norden 1967).

Examination of Pigeon Lake larval collections showed alewife larvae first appeared in early June suggesting that alewife spawning in this small inland lake occurred sometime in May. All locations of alewife spawning sites in Pigeon Lake are not known. However, on several occasions at night during late June and July, alewife were thought to have been observed spawning off beach station V (undisturbed Pigeon

TABLE 57. Scientific name, common name and abbreviations for all species of larvae captured from Campbell Plant study areas from June through December 1977. An L denotes presence of larvae in either Lake Michigan or Pigeon Lake, and an F represents fry. Names assigned according to Bailey et al. 1970.

Scientific and Common Name	Abbreviation	Pigeon Lake	Lake Michigan	Entrainment
Atherinidae				
Labidesthes sicculus (Cope) Brook silverside	SV	L,F		
Centrarchidae				
Ambloplites rupestris (Rafinesque) Rock bass	RB	L,F		
Lepomis cyanellus (Rafinesque) Green sunfish	GN	L		
Lepomis gibbosus (Linnaeus) Pumpkinseed	PS	L	F	
Lepomis macrochirus Rafinesque Bluegill	BG	F	F	F
Lepomis spp. Unidentified *Lepomis*	XL	L,F	L	
Micropterus dolomieui Lacépède Smallmouth bass	SB	L		
Micropterus salmoides (Lacépède) Largemouth bass	LB	L,F	L	
Pomoxis nigromaculatus (Lesueur) Black crappie	BC	L,F		
Pomoxis spp. Unidentified *Pomoxis*	PM	L	L	
Centrarchidae spp. Unidentified centrarchid	CT	L		
Clupeidae				
Alosa pseudoharengus (Wilson) Alewife	AL	L,F	L,F	L,F
Dorosoma cepedianum (Lesueur) Gizzard shad	GS			F
Cottidae				
Cottus cognatus Richardson Slimy sculpin	SS		L	
Myoxocephalus quadricornis (Linnaeus) Fourhorn sculpin	FS		L	

TABLE 57. (continued).

Scientific and Common Name	Abbreviation	Pigeon Lake	Lake Michigan	Entrainment
Cyprinidae				
Cyprinus carpio Linnaeus Carp	CP	L,F	L	L
Notemigonus crysoleucas (Mitchill) Golden shiner	GL	L,F		
Notropis atherinoides Rafinesque Emerald shiner	ES	F		
Notropis hudsonius (Clinton) Spottail shiner	SP	L,F	L,F	L,F
Pimephales notatus (Rafinesque) Bluntnose minnow	BM	L,F		
Cyprinidae spp. Unidentified cyprinid	XM	L,F	L,F	L
Gasterosteidae				
Pungitius pungitius (Linnaeus) Ninespine stickleback	NS	L		F
Gasterosteidae spp. Unidentified stickleback	XG	L	L	
Ictaluridae				
Ictalurus nebulosus (Lesueur) Brown bullhead	BN	F		
Ictalurus spp. Unidentified bullhead	XB	L,F		
Noturus gyrinus (Mitchill) Tadpole madtom	MT	F		
Osmeridae				
Osmerus mordax (Mitchill) Rainbow smelt	SM	L,F	L,F	L,F
Percidae				
Etheostoma nigrum Rafinesque Johnny darter	JD	L,F	F	
Etheostoma spp. Unidentified *Etheostoma*	XE	L		L
Perca flavescens (Mitchill) Yellow perch	YP	L,F	L	L
Percopsidae				
Percopsis omiscomaycus (Walbaum) Trout-perch	TP		L	L

TABLE 57. (continued).

Scientific and Common Name	Abbreviation	Pigeon Lake	Lake Michigan	Entrainment
Larvae damaged beyond recognition	XP	L	L	L,F
Unidentified Pisces	XX	L	L	L

Lake) and around openwater station M (influenced by Lake Michigan) in Pigeon Lake. There was periodic splashing heard in a large area around the boat which we identified as spawning alewives. From our other Lake Michigan work experience and because we observed large quantities of larval alewives in the water at night with flashlights offshore from beach station V, we are confident that large numbers of alewives were spawning in Pigeon Lake. Spawning in the Escanaba area of Lake Michigan (Delta Co. Michigan) occurred in 0.6-0.9 m of water over mud, sand and organic, debris-covered bottom (Joeris and Karvelis 1962). If selection of similar habitat occurred in Pigeon Lake, this would explain the increased numbers of alewife larvae observed at beach stations S and T when compared with openwater stations (Fig. 73).

A length-frequency histogram of all alewife larvae caught during June in Pigeon Lake (Fig. 74) shows that most larvae ranged between 4-11 mm (average = 7.2, S.E. = 0.3). Norden (1967) reported that newly hatched larvae averaged 3.8 mm. If the growth rate of 0.5 mm per day reported by Lam and Roff (1976), or 0.56 mm per day reported by Heinrich (1977) was experienced by alewife larvae in Pigeon Lake, most larvae captured there in early June hatched within 10 days prior to capture. A length-frequency histogram for alewife larvae captured in the intake canal (station Z) during June (Fig. 74) showed all larvae there were between 3.5-5.0 mm (undoubtedly newly-hatched). These smaller larvae were probably entrained at higher rates than longer larvae which were present in Pigeon Lake, because newly-hatched larvae appeared to have a species-specific length below which they are apparently semi-planktonic and thus susceptible to intake currents. Once they are larger than that length, larvae appear to exert more control over their movements and therefore their distribution. Behavioral movements in response to food, light, currents and other factors then determine their future vulnerability to being entrained. Our data indicate that Pigeon Lake serves as an important area for early spawning of alewife.

No alewife larvae were present in Lake Michigan samples collected in early June with the exception of 73 larvae/1000 m^3 observed at beach station R (n. discharge) (Fig. 75). The larva observed was 4.5 mm and

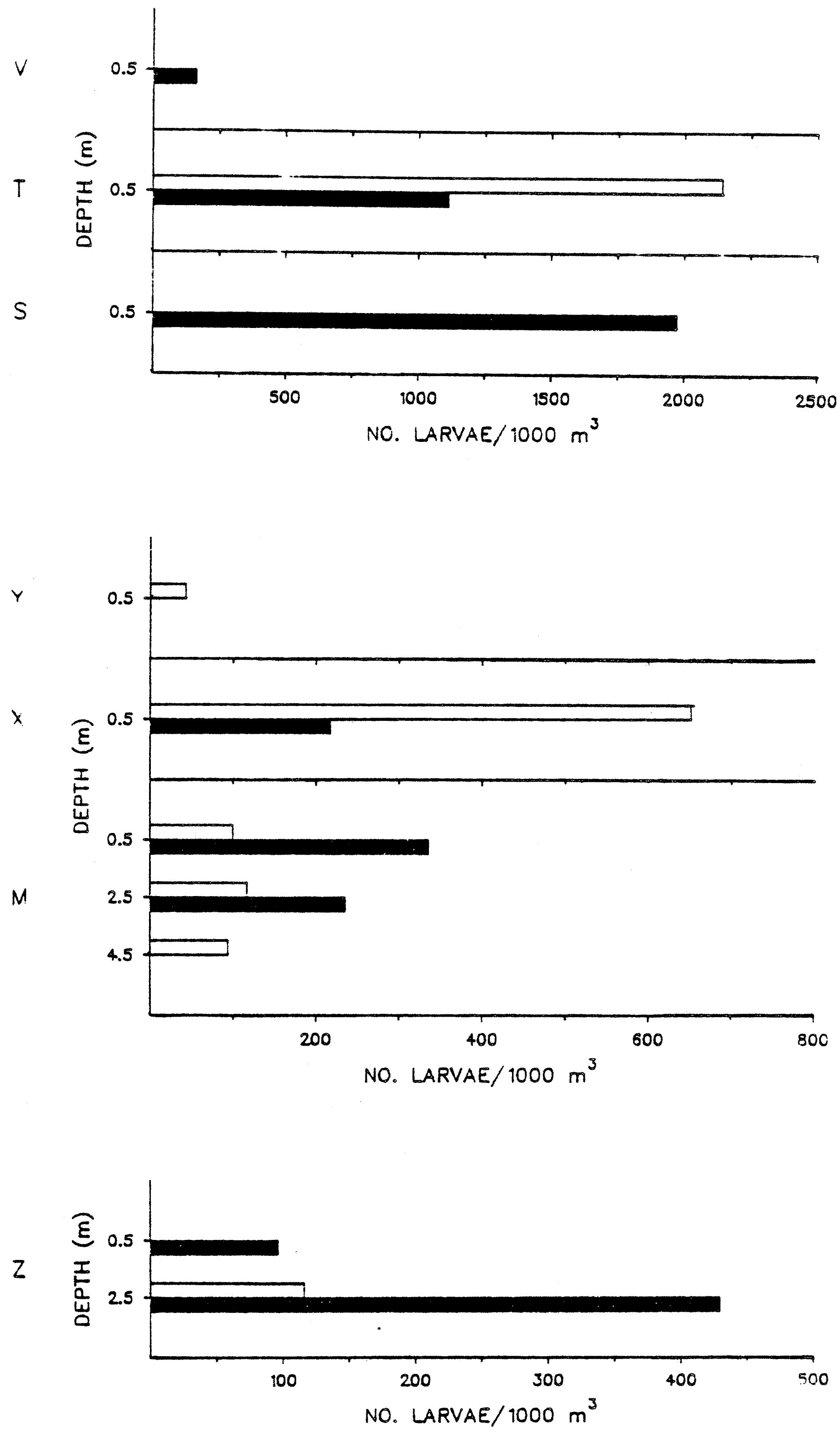


FIG. 73. Number of alewife larvae per 1000 m^3 for beach, openwater and intake canal stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 31 May - 3 June 1977. □ = Day ■ = Night

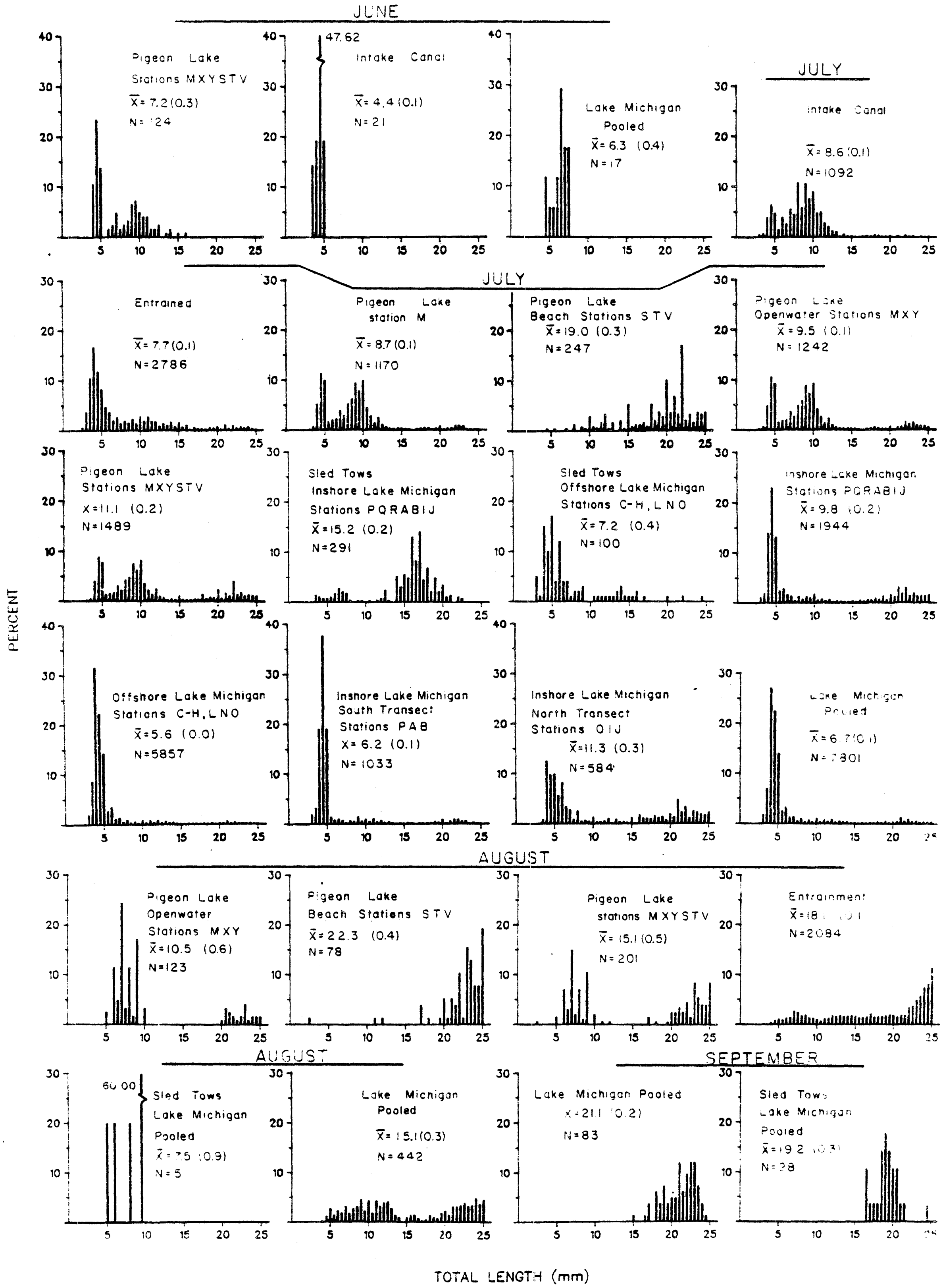
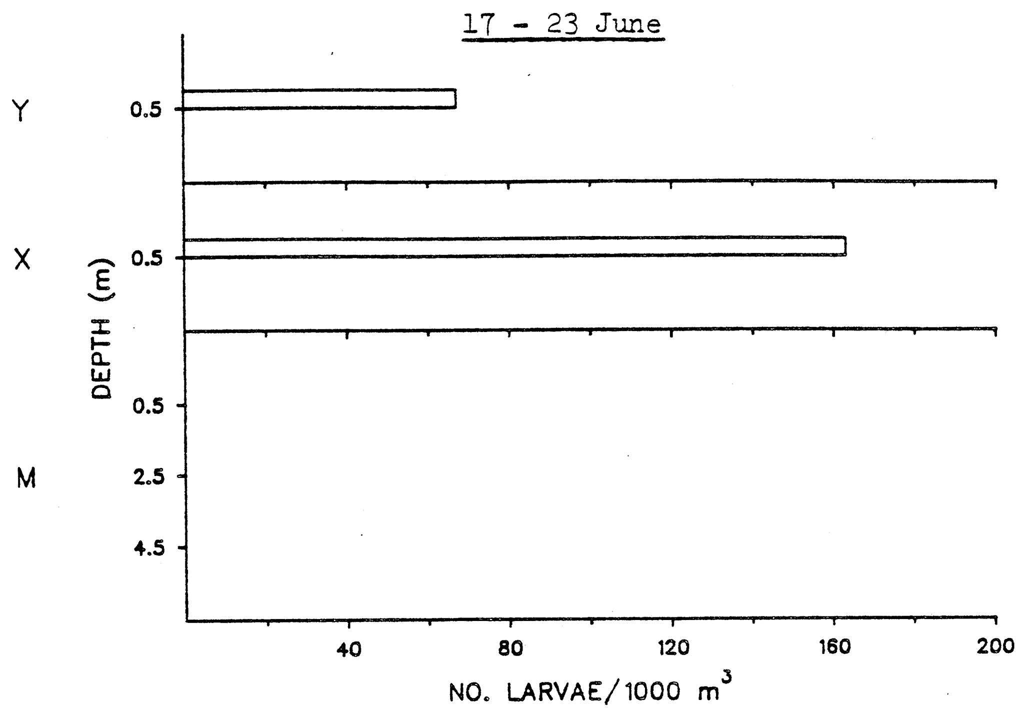


FIG. 74. Length-frequency histogram for larval alewife caught at selected pooled stations in Lake Michigan and Pigeon Lake near the J.H. Campbell Plant, 1977. All tows were net tows unless sled tows were specified. ($\overline{X}$=mean, N=total number of larvae used in the comparison, standard error is given in parenthesis.)



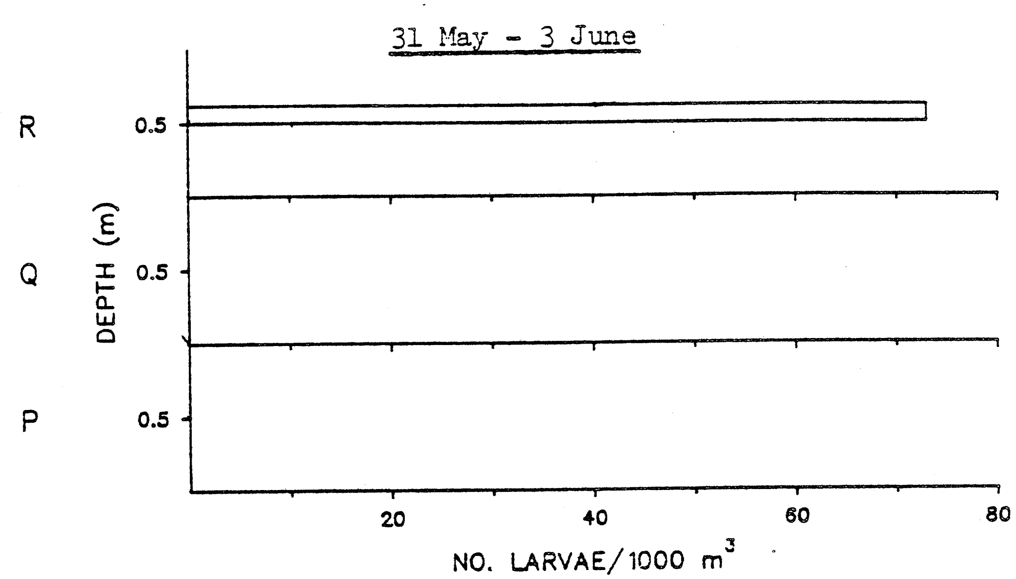


FIG. 75. Number of alewife larvae per 1000 m^3 for openwater Pigeon Lake stations (17-23 June) and Lake Michigan beach stations (31 May-3 June) near the J. H. Campbell Plant, eastern Lake Michigan, 1977.
□ = day ■ = night

suggests that alewife spawning occurred in the area of the discharge canal near the same time as spawning occurred in Pigeon Lake. Concentrations of up to 429 alewife larvae/1000 m^3 were noted in the intake canal (station Z) at night in early June, but unfortunately no entrainment samples were taken, which may have clarified the origin of larvae collected at beach station R. Preliminary observations of high densities of eggs in samples taken in the discharge canal in June 1978, coincident with observations of high numbers of adult alewives which appeared to be spawning, suggests the discharge canal as the source of station R alewife larvae. Based on data summarized by Marcy (1975) indicating that the vast majority of power plants inflicted near 100% mortality on entrained larvae (particularly those with long discharge canals), it was unlikely that larvae observed at beach station R (n. discharge) originated in Pigeon Lake and passed through the plant.

In late June no alewife larvae were collected at beach stations in Pigeon Lake, and decreased numbers were found at openwater stations M and X when compared with early June densities (Fig. 75). Numbers of alewife larvae at openwater station Y (influenced by Pigeon River) in late June were comparable to concentrations observed in early June (Figs. 73 and 75). No alewife larvae were collected from the intake canal (station Z) in late June. In general, decreased densities of alewife larvae in Pigeon Lake were probably the result of a tapering off of a spawning peak in Pigeon Lake. This spawning peak undoubtedly was responsible for the high densities of alewife larvae observed in Pigeon Lake in early June. Natural larval mortality, predation, movement from the area, as well as entrainment may also account for the observed reduced alewife densities in late June.

Lake Michigan south transect samples in late June showed a sporadic occurrence of alewife larvae at offshore stations 12-21 m (Fig. 76), with no larvae found at shallower depths. However, at the north transect in late June a concentration of 21 larvae per 1000 m^3 was observed at shallow water station L (6 m). Average size of larvae in Lake Michigan samples at this time was 6.3 mm, S.E.=0.4 (Fig. 74), indicating these were newly hatched during the previous week. These occurrences of larvae in Lake Michigan in late June were the initial indications of successful alewife hatching in Lake Michigan. Absence of alewife larvae in shallower water where they might be expected to occur first was puzzling. It is possible that water currents produced by winds were responsible for dispersal of alewives to deeper water. Wind was considered to be a dominant factor in bringing about dispersal of haddock larvae in the North Sea (Saville 1965) and walleye larvae in Oneida Lake, New York (Houde and Forney 1970). Weather data at time of sampling alewife larvae in June indicated that winds ranged from 0-15 mph from the south to southwest. Observations on 23 June indicated the longshore current was proceeding north to south. The combination of more immediate wind-driven currents and longshore currents may have

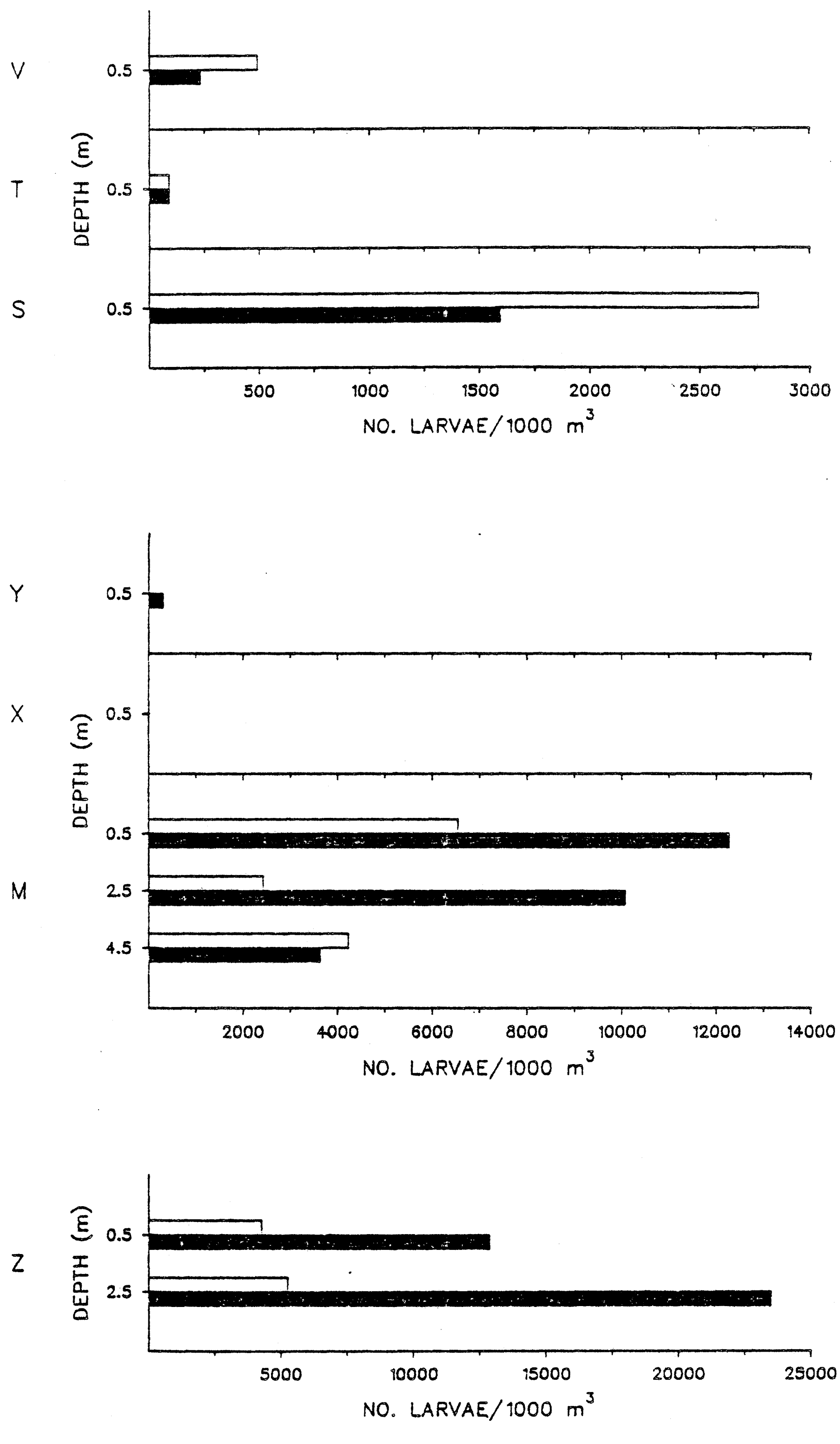


FIG. 76 . Number of alewife larvae per 1000 m^3 for beach, openwater and intake canal stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 7-10 July 1977.
☐ = Day ■ = Night

created subsurface currents offshore, moving larvae in that direction also. It is also possible that alewives had spawned in deeper water.

In early July, at both north and south Lake Michigan transects, dramatic increases were noted in the concentration of alewife larvae collected at all stations and depths (Fig. 77) indicating that increased spawning in Lake Michigan had occurred by late June. High average numbers of eggs (0-985 eggs/1000 m^3), which were probably alewife, began to appear at Lake Michigan beach stations P (s. reference), Q (s. discharge) and R (n. discharge) in June. High concentrations of alewife larvae in Pigeon Lake in early July (Fig. 78) may be due to spawning by alewife in Pigeon Lake, as well as passage of Lake Michigan water containing larvae into Pigeon Lake. The magnitude of concentrations of alewife larvae decreased with diminishing influence of Lake Michigan on Pigeon Lake stations. Pigeon Lake, station M (6 m) and beach station S (influenced by Lake Michigan) in early July had the highest number of alewife larvae per 1000 m^3 (over 12,000 and 2500 respectively) with less reported at beach station V (undisturbed by Pigeon Lake) and the least number of larvae reported at stations X and T, which are more removed from the influence of Lake Michigan (Fig. 78).

No larvae were collected at station Z (intake canal) in late June, while high numbers of alewife larvae were found in early July both at station Z (intake canal) and in entrainment samples (Fig. 78 and Appendix 10). The high concentration of larvae at these two stations (2066-23,494 larvae/1000 m^3) was probably the result of peak spawning in Lake Michigan during late June. Entrainment of larvae in early July was the highest observed, with 4.6 million larvae (all species included) passing throught the plant over a 24 hr period (Appendix 10). Examination of length-frequency data for just Lake Michigan field-caught larvae in July (Fig. 74) indicated that over 70% ranged between 3.0-6.0 mm (mean 6.7, S.E. = 0.1). Over 58% of all alewife larvae entrained in July were in this 3.0-6.0 mm range (mean 7.7 S.E. = 0.1), indicating a substantial number of newly hatched, entrained larvae may have come from Lake Michigan. Length-frequency histograms from station Z (intake) and Pigeon Lake station M (influenced by Lake Michigan) in July, representing water which was most immediate to being entrained also showed that substantial numbers of small 3.5-10 mm alewife were present (Fig. 74). A composite histogram for all Pigeon Lake larvae indicated that these larvae were generally larger and probably did not represent a major portion of larvae entrained at this time. A length-frequency comparison between Pigeon Lake openwater stations and Pigeon Lake beach stations in July (Fig. 74) revealed that smaller larvae (<12 mm) were generally found at the deeper openwater stations, whereas larger larvae (>15 mm) tended to be more abundant at beach areas. The reason for this distribution is unclear but it is undoubtedly related to net avoidance and the fact that smaller larvae were more passively moved by currents into deeper water, whereas larger larvae maintained themselves close to

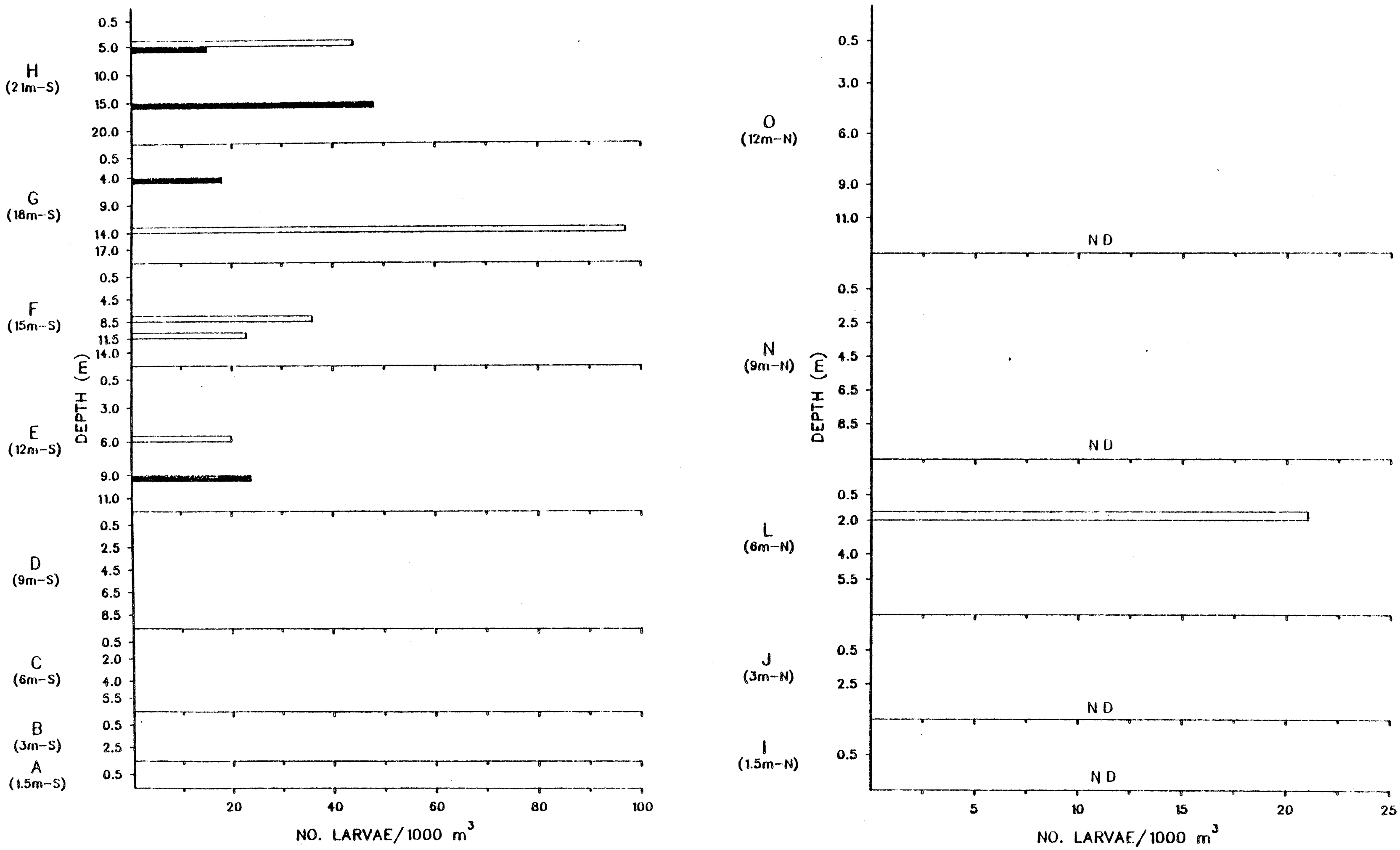


FIG. 77. Number of alewife larvae per 1000 m^3 for openwater Lake Michigan stations near the J. H. Campbell Plant, eastern Lake Michigan, 17-23 June 1977. □ = Day ■ = Night
ND = no data

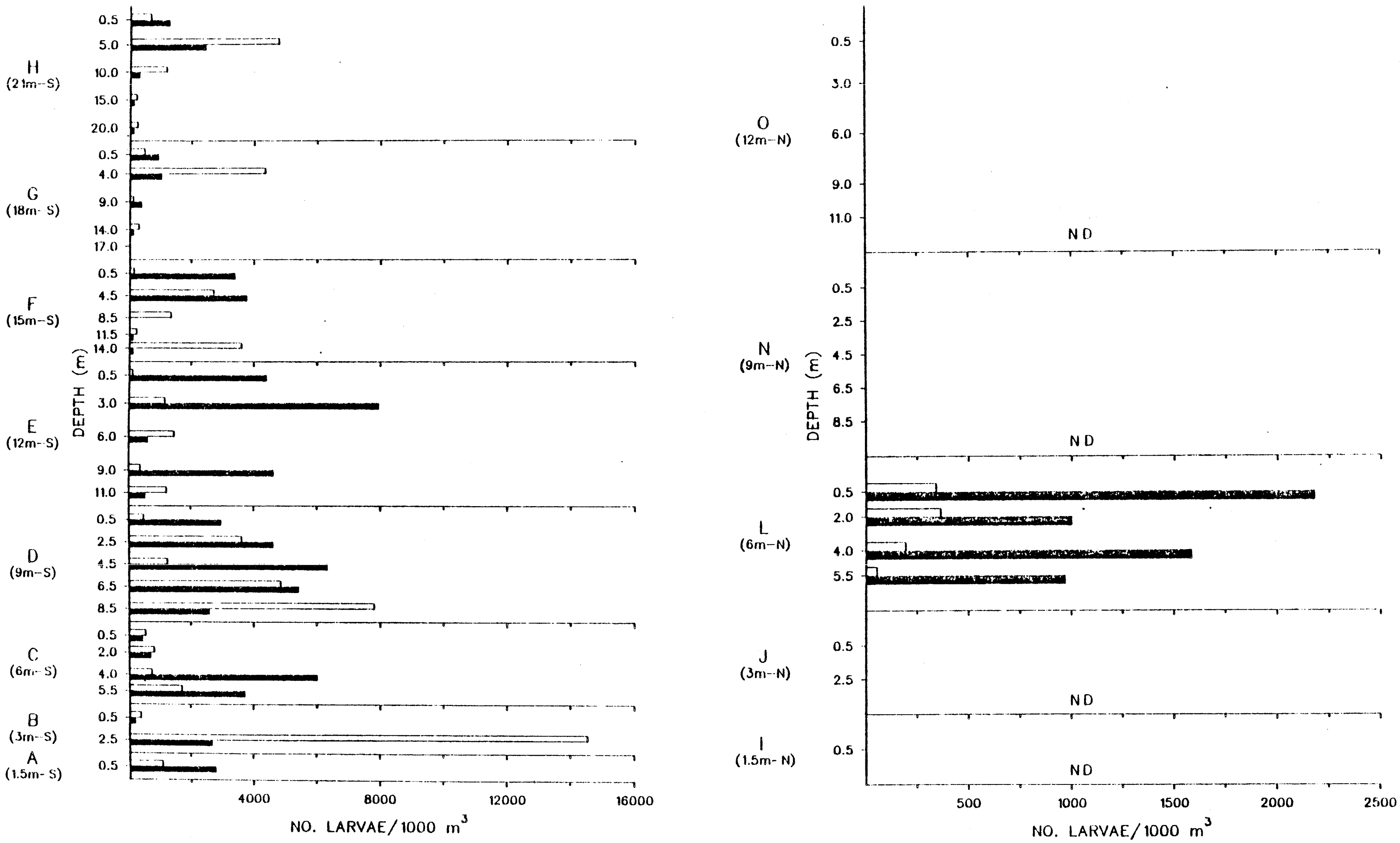


FIG. 78 . Number of alewife larvae per 1000 m^3 for openwater Lake Michigan stations near the J. H. Campbell Plant, eastern Lake Michigan, 7-10 July 1977. ☐ = Day ■ = Night
ND = no data

shore. Most spawning may also occur in the openwater of Pigeon Lake.

In Lake Michigan, high concentrations of alewife larvae were observed in early July at s. discharge beach station Q (1635-3151 larvae/1000 m^3) and n. discharge beach station R (1835-8846/1000 m^3) as opposed to openwater tows at the 6 m n. station L (54-2176 larvae/1000 m^3) (Figs. 77, 79). The difference in concentration of larvae found at beach versus inshore stations may be due to the preference of alewife larvae for warmer water. Water temperatures at beach stations Q and R were 31.5 C and 24.2 C respectively; whereas, at openwater station L (6 m - n.) water temperatures were 17-21 C. Extraordinarily high concentrations of alewife larvae (8846 larvae/1000 m^3) were noted at beach station R (n. discharge) at night. These high concentrations of alewife larvae at stations R and Q (near the present discharge canal) for both early July and mid-July (Fig. 79) when reference beach station P had low concentrations may possibly be due to recruitment of larvae from adults which spawned earlier in the discharge canal. A length-frequency comparison of south inshore stations P (s. reference), A (1.5 m - s.) and B (3.0 m - s.) with north inshore stations Q, R (discharge), I (1.5 m - n.) and J (3 m - n.) indicated that a substantial portion of larvae at north inshore stations were larger (>15 mm). These larvae were probably early spawned larvae dispersing from their nursery and spawning area, the discharge canal. Thus the two apparent peaks indicated by the length-frequency histogram at north inshore transect stations probably reflects the difference in spawning peaks between Lake Michigan and the discharge canal. The larger alewife larvae observed during July in Lake Michigan (Fig. 74) were approximately the same length as alewife larvae found at Pigeon Lake beach stations in July, supporting the contention of similar peak spawning peak times for alewife in Pigeon Lake and the discharge canal.

Mid-July samples (13 July) were only taken from Lake Michigan north transect stations (I-1 m, J-3 m, L-6 m, R-beach, n. discharge). Results of these collections indicated that high concentrations of alewife larvae, up to 6200 larvae/1000 m^3 were present (Fig. 80). Concomitantly, numbers of alewife larvae entrained on 14 July decreased considerably (Appendix 10), which may be due to larvae reaching such a size that they can more easily stay in a preferred area. Even if larvae do reach the intake canal they can resist or orient to currents and thus maintain themselves there, decreasing their vulnerability. Thus peak entrainment of alewive larvae seems to occur shortly after a hatching peak when small larvae are planktonic and passively moved by currents.

Lake Michigan south transect openwater stations experienced significant declines in the concentration of alewife larvae found on 25-28 July when compared with early July (Figs. 77, 81). Interestingly, alewife concentrations at beach station P (s. reference) did not exhibit this decline (Fig. 79).

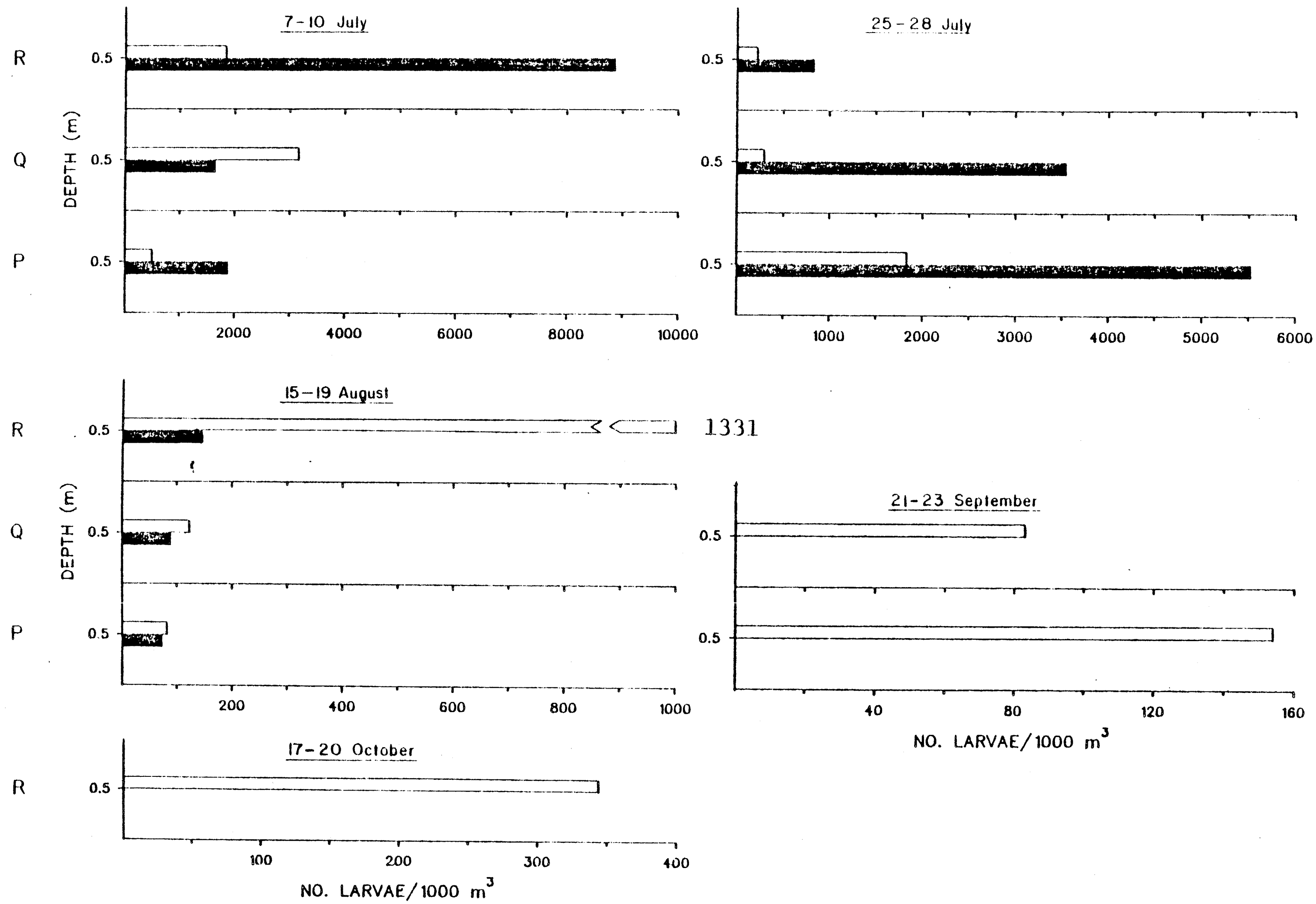


FIG. 79 . Number of alewife larvae per 1000 m^3 for Lake Michigan beach stations near the J. H. Campbell Plant, eastern Lake Michigan, 1977. ☐ = Day ■ = Night

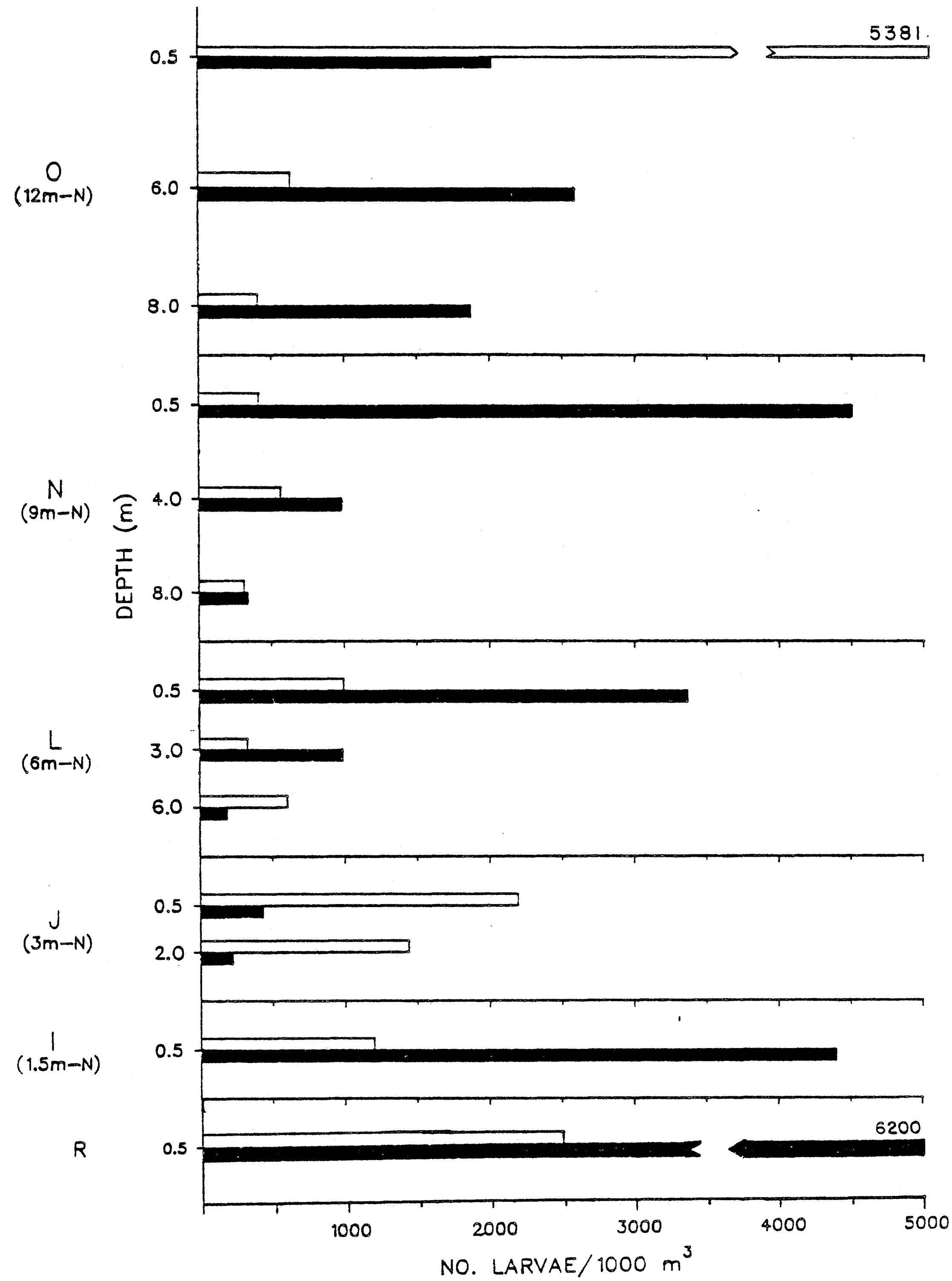


FIG. 80. Number of alewife larvae per 1000 m^3 for Lake Michigan stations (north transect and beach station R - n. discharge) near the J. H. Campbell Plant, eastern Lake Michigan, 13 July 1977. Samples were only collected at surface, mid-depth and near bottom at all stations deeper than 3 m.
☐ = day ■ = night

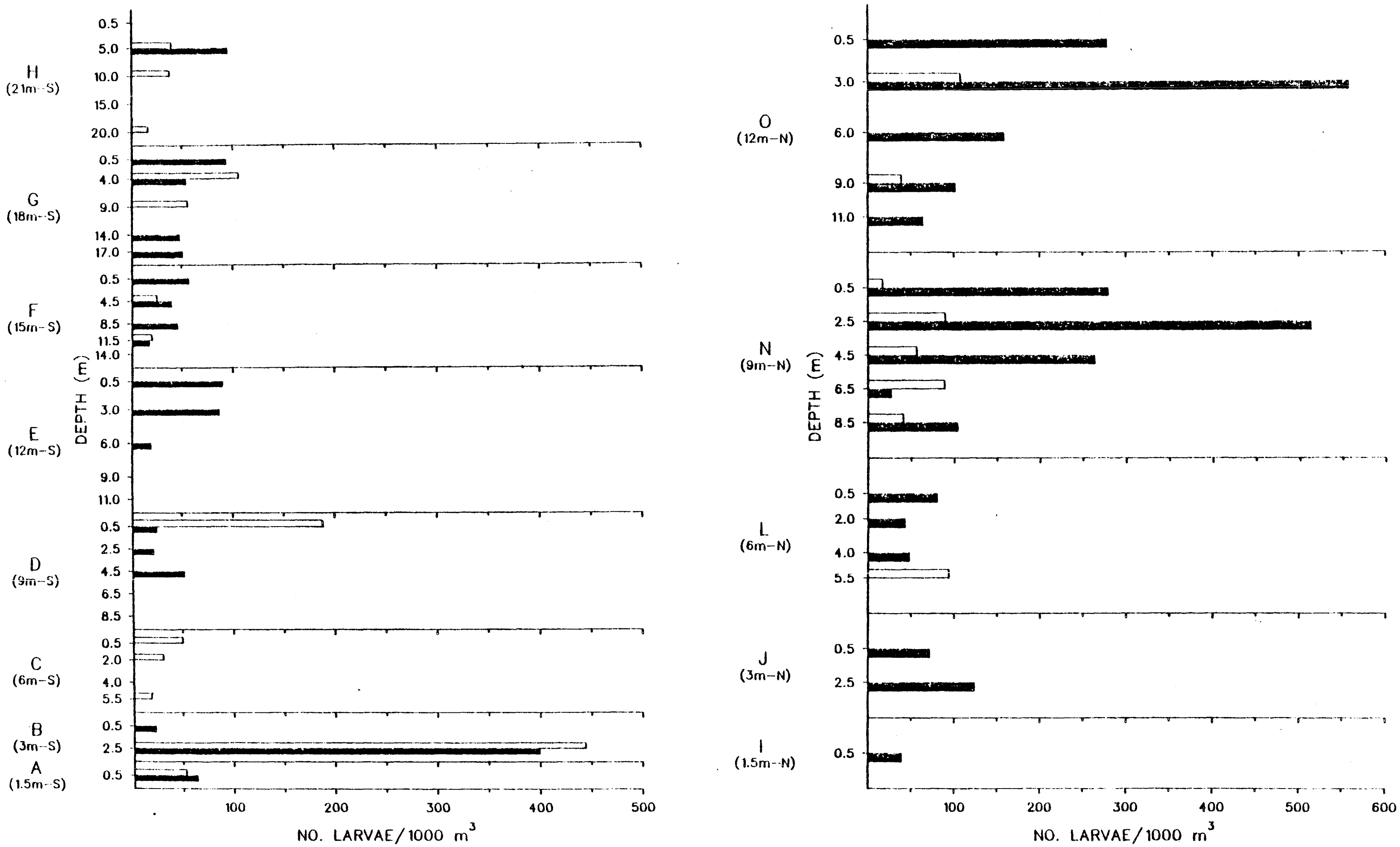


FIG. 81. Number of alewife larvae per 1000 m^3 for openwater Lake Michigan stations near the J. H. Campbell Plant, eastern Lake Michigan, 25-28 July 1977. □ = Day ■ = Night

Nearshore waters in late July had temperatures between 15.5-16.0 C and may have been selected by alewife larvae over cooler offshore waters. Stations A (1.5 m - s.) and B (3 m - s.) in late July had water temperatures between 10.8-13.0 C, and also seemed to have higher alewife concentrations than other stations with cooler water temperatures (Fig. 81). Low water temperatures at Lake Michigan stations in late July were undoubtedly caused by an upwelling of cooler water, since water temperatures in early July and August were much higher in comparison. In general, the sporadic occurrence of high concentrations of alewife larvae in late July at the Lake Michigan south transect was usually related to higher water temperatures.

Since many of the larvae observed in late July were smaller larvae (3-6 mm), it is unlikely that these larvae were exhibiting an active preference for warmer water temperatures. It was more likely that warmer water, containing larvae hatched in mid-July was replaced by cooler upwelled water (containing few larvae). A mixing of these two masses of water was probably incomplete at the time of sampling. Larger larvae (>15 mm) observed at warmer water temperatures may be exhibiting an active preference for warmer water as was observed by Jude et al. (1979).

North transect collections in late July when compared to samples procured in early July also experienced a decrease in the number of alewife larvae found similar to that observed at the south transect (Fig. 77, 80 and 81). It appeared from our data that north offshore Lake Michigan stations (L-6 m to O-12 m) had consistently more larvae in late July than comparable stations to the south (C-6 m to E-12 m). Examination of water temperature data (Appendices 6 and 7) from late July indicated that stations L-6 m to O-12 m north had elevated temperatures at all depths (6.0-13 C, most above 10 C) compared with stations C-6 m to E-12 m south which had temperatures from 5-13 C, mostly below 10 C. North transect elevated water temperatures, apparently preferred by alewife larvae, allowed a more even distribution of alewife larvae at all depths; whereas they were found mainly in the warmer surface waters at south transect stations. It is evident that upwelled colder water was thoroughly mixed with discharge water at north stations causing alewife larvae to be widely distributed throughout the entire water column in this area during late July. Thus the apparent differences in larvae distribution between north and south transects may only occur during times of upwellings. Again beach station collections along both transects exhibited continued high numbers of alewife larvae during late July which was probably due to higher water temperatures (Fig. 79). It is interesting to note that extraordinarily high average concentrations of eggs (up to 511,700 eggs/1000 m^3, Appendices 6 and 7) were found at beach stations P, Q and R indicating the distinct possibility of continued alewife spawning there through 25-28 July.

Sled tow data for late July (Appendix 9) indicated that alewife larvae in the bottom strata at south transect stations were more concentrated at shallower depths. Lake Michigan south beach station P (s. reference) and openwater stations A (1.5 m - s.) to C (6 m - s.) had notably higher bottom strata concentrations (72-1084 larvae/1000 m^3) than stations D (9 m - s.) to H (21 m - s.) which had 0-475 larvae/1000 m^3. There was no apparent relationship between water temperature and alewife density since no notable differences in water temperature were observed between depths, other than the 16.0 C temperature at the south beach station P which was higher than the 6.0-9.8 C measured at other stations (Appendix 6). Highest concentrations of alewives from north transect bottom sled tows were observed at inshore beach station Q (835-1372 larvae/1000 m^3) and R (5261 larvae/1000 m^3), as well as at the 1.5 m station I where an extremely high concentration of 15,884 larvae/1000 m^3 was found.

Length-frequency comparisons of alewife larvae captured during inshore July sled tows at Lake Michigan beach stations (P, Q, R), 1.5 m stations (A, I) and 3 m stations (B, J) compared with inshore stations C (6 m - s.) to H (21 m - s.) and L (6 m - n.) to O (12 m - n.), indicated that smaller alewife larvae were more frequently found at offshore stations, and larger alewife larvae tended to occur more frequently at inshore stations (Fig. 74). This was also illustrated by a similar comparison using net tow data (Fig. 74).

Extremely low densities of entrained alewife were observed on 29 July (20-26 larvae/1000 m^3) when compared with weeks both previous and after collection of these samples. An upwelling in Lake Michigan on 29 July was suspected as being responsible for this observation and gives credence to the hypothesis that many alewife larvae eventually entrained were derived from Lake Michigan. An intake water temperature of 12.5 C was recorded on 29 July; whereas, temperatures of 22.8-23.4 C were recorded on 21 July and 18.3-19.4 C on 3 August. Lower water temperatures in the intake canal (station Z) in late July also coincided with lower alewife concentrations (Figs. 78 and 82).

Pigeon Lake station M (6 m) in late July also had water temperatures of 10.0-11.7 C; when few (Fig. 82) alewife larvae were found. Pigeon Lake beach stations S and V, as well as openwater station X (0.5 m) which had warmer water had alewife concentrations up to 1865 larvae/1000 m^3 (Fig. 82) indicating that upwelled water displaced warmer Pigeon Lake water. Alewives in the outlying warmer areas were not subject to entrainment, while water being drawn into the plant from Lake Michigan contained fewer larvae causing lower entrainment values.

During August sampling, water temperatures at Lake Michigan south transect stations were elevated at all depth strata, with the exception

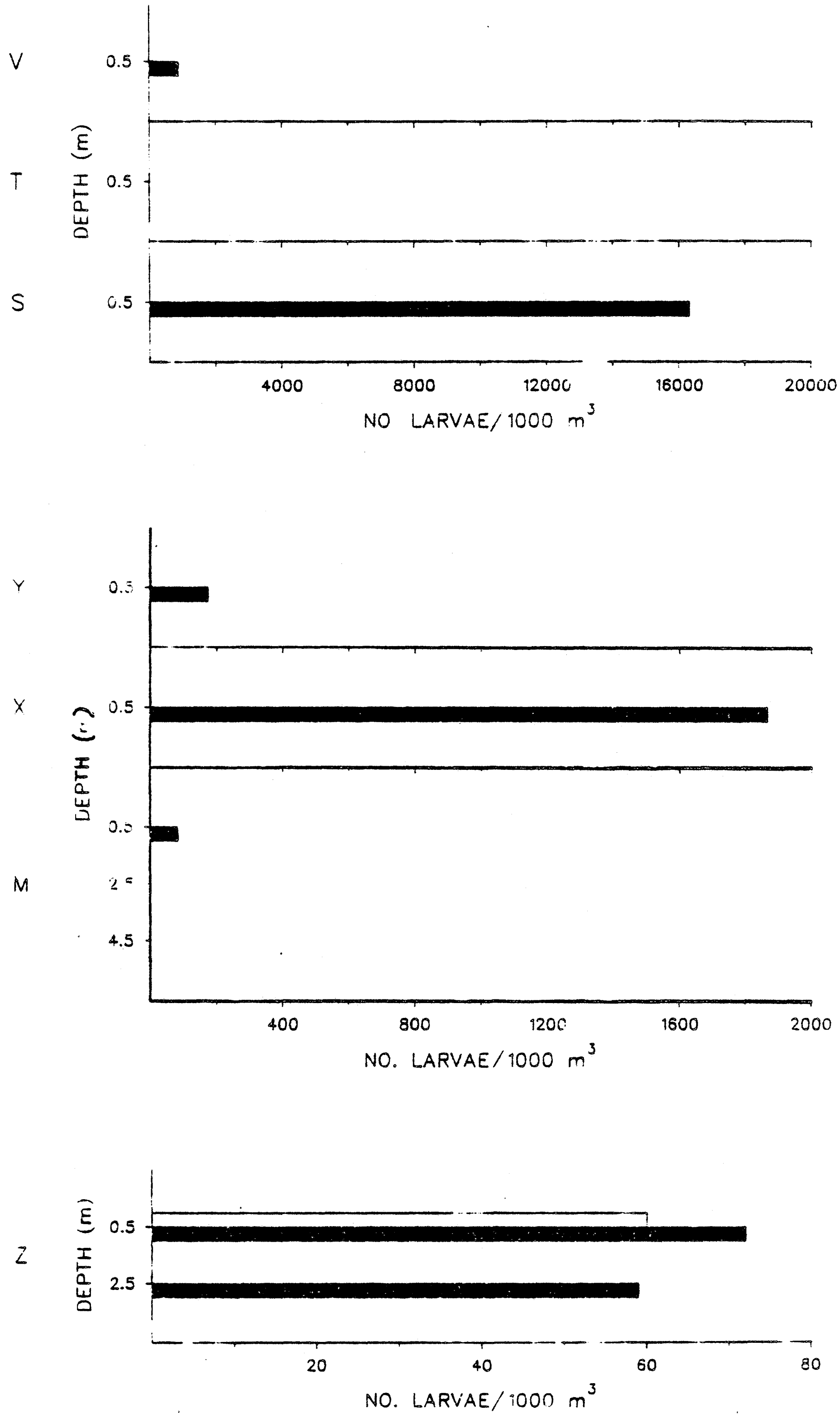


FIG. 82. Number of alewife larvae per 1000 m^3 for beach, openwater and intake canal stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 25-28 July 1977. □ = Day ■ = Night

of the bottom, when compared with July values. This apparently allowed alewife larvae to become more widely distributed throughout the water column (Fig. 83) which was similar to the distributional pattern observed at north transect stations in late July (Fig. 81).

North transect stations in mid-August also showed alewife larvae to be widely distributed throughout all depth strata, with somewhat higher concentrations observed at beach station R (n. discharge) (Figs. 79, 83). Eggs were noticeably absent from all Lake Michigan samples on 15-19 August indicating possible cessation of alewife spawning (Appendix 6 and 7). Occurrence of alewife larvae in sled tow samples from Lake Michigan stations was sporadic during mid-August, with measurable concentrations recorded from stations E (12 m - s., 18 larvae/1000 m^3), G (18 m - s., 72 larvae/1000 m^3) and J (3 m - n., 58 larvae/1000 m^3). All larvae caught in sled tows during August were small (<10 mm) larvae (Fig. 74).

In Pigeon Lake, alewife larvae during mid-August were found primarily at stations influenced by Lake Michigan (M - 6 m and S - beach) with some caught at beach station V (undisturbed Pigeon Lake) and openwater station X (undisturbed Pigeon Lake) (Fig. 84). The intake canal (Z) had concentrations up to 249 alewife larvae/1000 m^3. Again the alewife length-frequency comparison of openwater Pigeon Lake stations with beach stations in Pigeon Lake (Fig. 74) indicated lower numbers of larger (>20 mm) alewife larvae and higher numbers of small larvae in deeper water. The reverse was true for beach stations.

Entrainment samples from 3 and 10 August contained relatively high concentrations of alewives (Appendix 10) when compared to July (with the exception of the upwelling period-late July). Sampling in Lake Michigan and Pigeon Lake was not performed concurrent with these earlier August entrainment samples.

Decreased concentrations of alewife in entrainment samples for late August, and the continuing decline through December, probably reflects growth of many larvae from the arbitrary "larvae" classification (less than 25.4 mm) into the "fry" classification (larger than 25.4 mm). The substantially increased number of fry observed in entrainment samples in August (9-2193 fry/1000 m^3, Appendix 11) substantiates this contention.

Density of alewife larvae entrained on 10 August was 1004-1108/1000 m^3, which then declined to 30-53/1000 m^3 on 16 August (Appendix 10). Numbers entrained on 16 August were low despite concentrations of 0-249 alewife larvae/1000 m^3 at the intake canal and high average values observed at Pigeon Lake beach station S (3223-4653 larvae/1000 m^3) and openwater 6 m station M (up to 3324 larvae/ 1000 m^3). Considerable numbers of fry (up to 549 fry/1000 m^3) were also found at these three stations. Reason for low entrainment of alewives on 16 August was

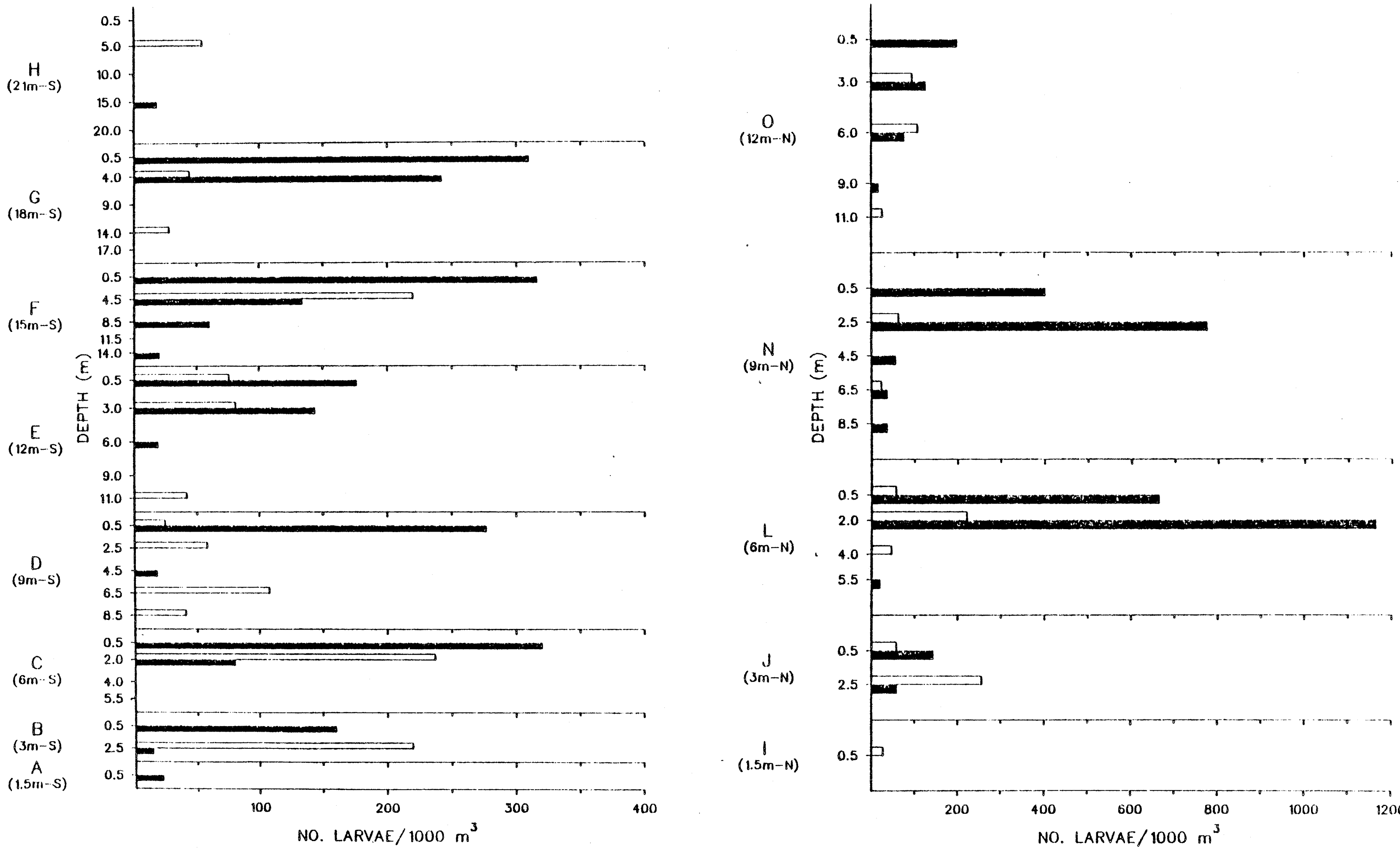


FIG. 83 . Number of alewife larvae per 1000 m^3 for openwater Lake Michigan stations near the J. H. Campbell Plant, eastern Lake Michigan, 15-19 August 1977. ☐ = Day ■ = Night

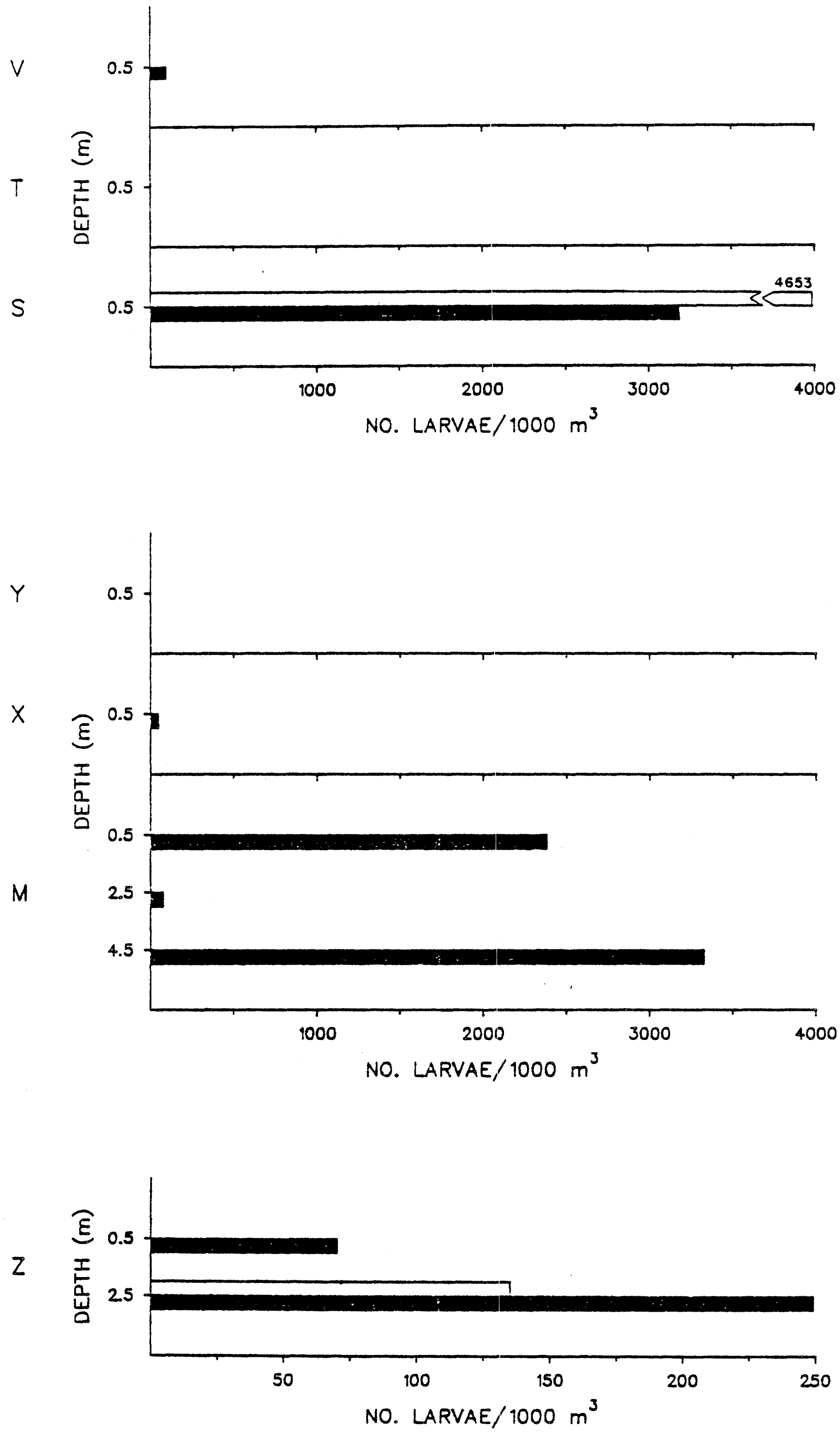


FIG. 84 . Number of alewife larvae per 1000 m^3 for beach, openwater and intake canal stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 15-19 August 1977. ☐ = Day ■ = Night

probably related to size of the larvae. A length-frequency histogram for Pigeon Lake and Lake Michigan (Fig. 74) indicated that many larvae were longer than 15 mm, and probably easily avoided or maintained themselves in the intake current. It is probable that factors other than inability of alewife to avoid intake canal current were responsible for the entrainment patterns observed. The drastic decline in the number of fry entrained between 10 and 16 August was undoubtedly related to the fact that fry had grown to a size that was no longer susceptible to entrainment, even at locations very close to the actual intake.

Alewife larval concentrations measured during September at Lake Michigan stations indicated that both north and south transects had similar concentrations and distributions of larvae (Fig. 85), with the exception of station A (1.5 m - s.) and B (3 m - s.) which had higher concentrations of alewives than comparable north transect station samples. Concentrations of alewives ranged from 0-351/1000 m^3 at these south stations as opposed to 0-37/1000 m^3 at north stations. In general, the trend during September at all Lake Michigan stations was a decline in alewife larvae concentrations, probably again due to larvae growth, mortality and increased ability of larvae to avoid the net. Larvae were longer than 15 mm both in September sled tows and openwater tows in Lake Michigan (Fig. 74).

There was a marked increase in densities of alewife larvae at inshore stations in Lake Michigan during daytime September sampling, compared with nighttime (Fig. 85). Inshore south transect Lake Michigan stations P (beach), A (1.5 m) and B (3 m) samples contained up to 361 larvae/1000 m^3 (Figs. 79 and 85) which was in sharp contrast with deeper south transect stations C (6 m) to H (21 m) where only two occurrences of larvae were observed during the day, one at station C (6 m - s.) at the surface (19 larvae/1000 m^3) and one at station D (9 m - s.) at a depth of 6 m (16 larvae/1000 m^3). Night samples from south transect stations, however, indicated that larvae concentrations were greatest at deepwater stations C (6 m - s., up to 30 larvae/1000 m^3) and D (9 m - s., up to 38 larvae/1000 m^3) when compared with shallower stations, demonstrating an offshore daily movement by this size alewife (>15 mm) (Fig. 85). Concentrations of 19 and 14 larvae/1000 m^3 were also observed at stations E (12 m - s.) and F (15 m - s.) respectively at night in September. Due to net avoidance during daylight hours by alewife in this size range (16.5-25.4, S.E. = 0.6) it is probable that concentrations of larvae at sampling stations during the day were underestimated. However, since net avoidance is appreciably diminished during dark hours, a movement of alewife from the beach zone to offshore waters at night was clearly indicated by our data.

This trend (described above) toward inshore movement by larval alewives during the day was also noted at the north transect stations in September when an average of 84 alewife larvae/1000 m^3 were observed at

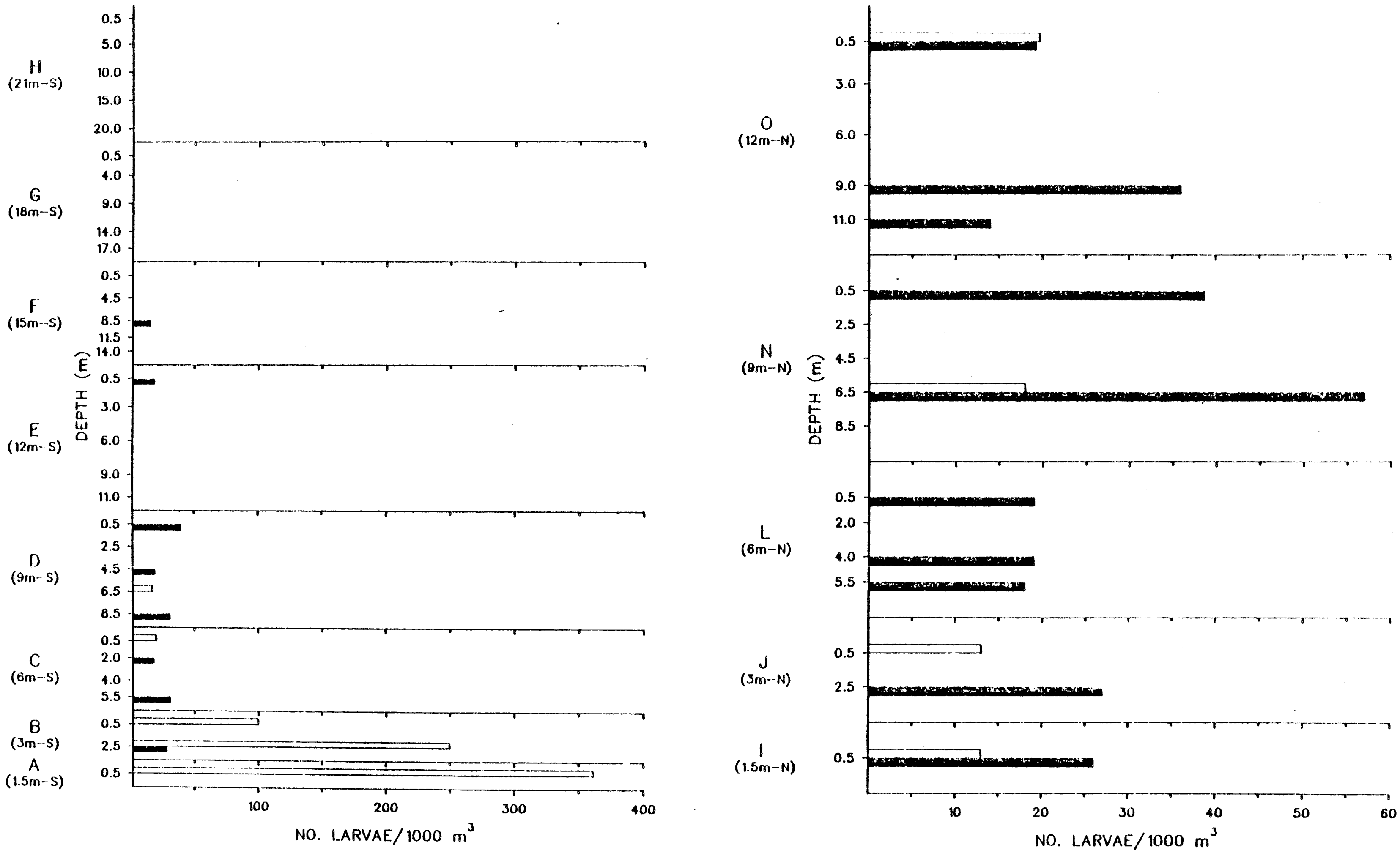


FIG. 85 . Number of alewife larvae per 1000 m^3 for openwater Lake Michigan stations near the J. H. Campbell Plant, eastern Lake Michigan, 21-23 September 1977. □ = Day ■ = Night

beach station Q (s. discharge) during the day; no larvae were found at night. Openwater stations L (6 m - n.) to O (12 m - n.) showed moderate concentrations at night (0-57 larvae/1000 m^3), but the tendency toward inshore movement during the day was not as distinct as exhibited at south transect stations in September.

Pigeon Lake data at this time in September showed alewife larvae were present at beach station S (influenced by Lake Michigan) during the day (4571 larvae/1000 m^3) and absent at this station at night (Fig. 86). However, at Pigeon Lake openwater station M (6 m), up to 136 larvae/1000 m^3 were observed at night during September, with an absence of larvae during the day. These data indicated a preference for inshore shallows by Pigeon Lake larval alewives during the day and offshore movement to deeper water at night, similar to that observed in Lake Michigan.

In October, no larvae were collected at Lake Michigan beach station P (s. reference); however there was an average density of 91 alewife fry/1000 m^3 in duplicate night samples. An average of 343 larvae/1000 m^3 was observed in day samples taken at beach station R (n. discharge), but no larvae were found at station Q (s. discharge). Fry densities at these north beach stations (Q and R) ranged up to 844 fry/1000 m^3 (Appendix 11). Although no openwater tows were taken in Lake Michigan during October, densities of larvae at Lake Michigan beach stations (P, Q and R) are indicative of a trend toward decreased numbers, similar to that observed in September. Observations of larvae in sled tow samples in October were sporadic, with larvae observed at stations C (6 m - s.), I (1.5 m - n.) and J (3 m - n.) in densities ranging from 20 to 36 larvae/1000^3 (Appendix 9).

Pigeon Lake samples from October contained no alewife larvae with the exception of 90 larvae/1000 m^3 observed at 1.5 m openwater station X (influenced by Pigeon River) and 45 and 78 larvae/1000 m^3 at night at station M (influenced by Lake Michigan) (Appendix 11). Entrainment in October was extremely low ranging from 373-7500 larvae entrained in a 24-hr period (Appendix 10). October alewife fry concentrations in Pigeon Lake (Appendix 11) were fairly comparable with late September densities and ranged from 0-78 larvae/1000 m^3. It was apparent that most alewives in October were able to maintain themselves in or away from the intake current, depending on their behavior and preferences.

No alewife larvae were found at any Lake Michigan stations in November. In contrast however, Pigeon Lake samples contained densities of larvae from 0-38/1000 m^3 with additional fry densities of 0-174 fry/1000 m^3 at openwater station M (6 m) (Fig. 87 and Appendix 11). Fry also occurred at station Z (intake canal) during November in concentrations up to 22 /1000 m^3 (Appendix 11).

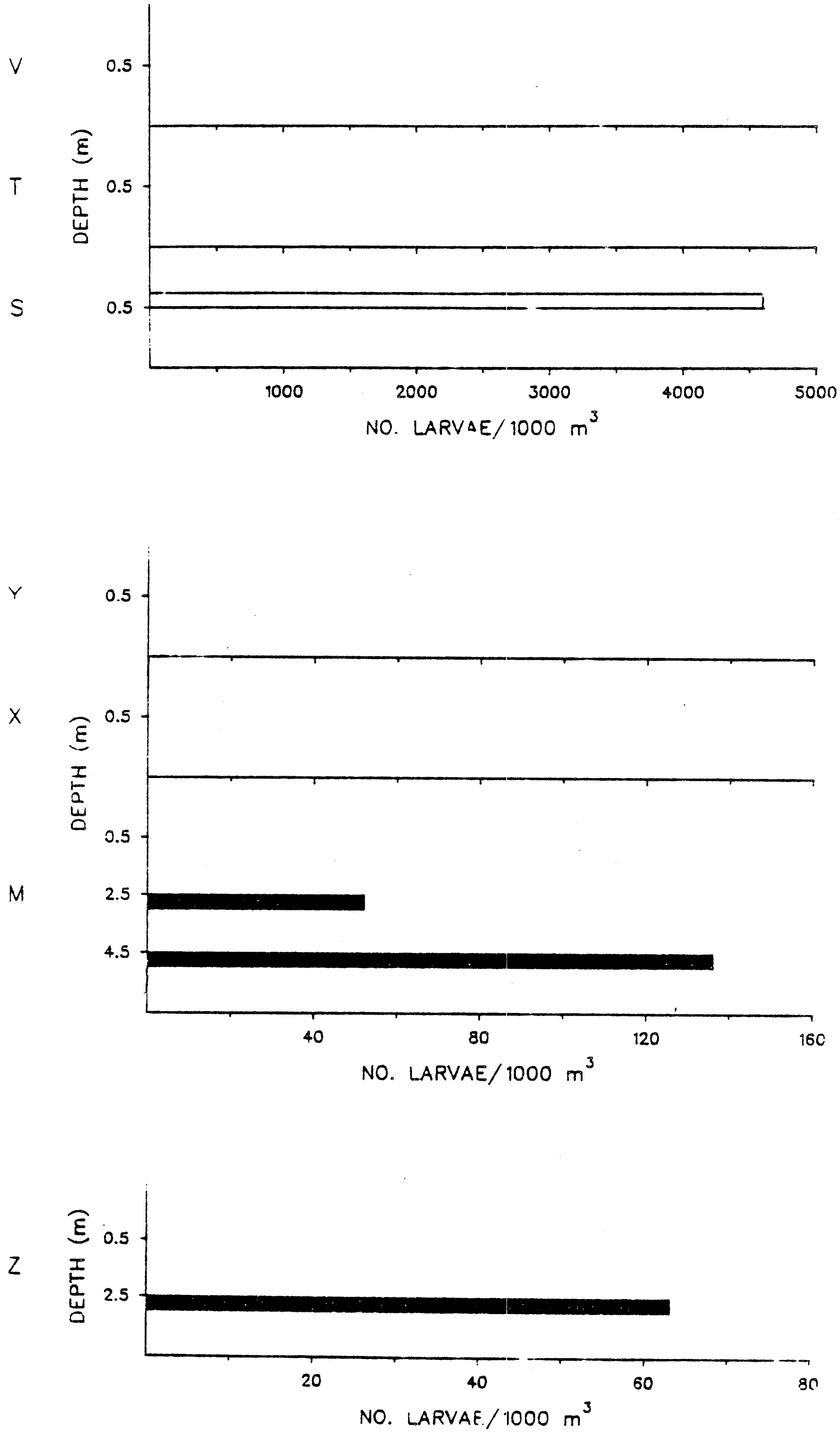


FIG. 86. Number of alewife larvae per 1000 m^3 for beach, openwater and intake canal stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 21-23 Setpember 1977. □ = Day ■ = Night

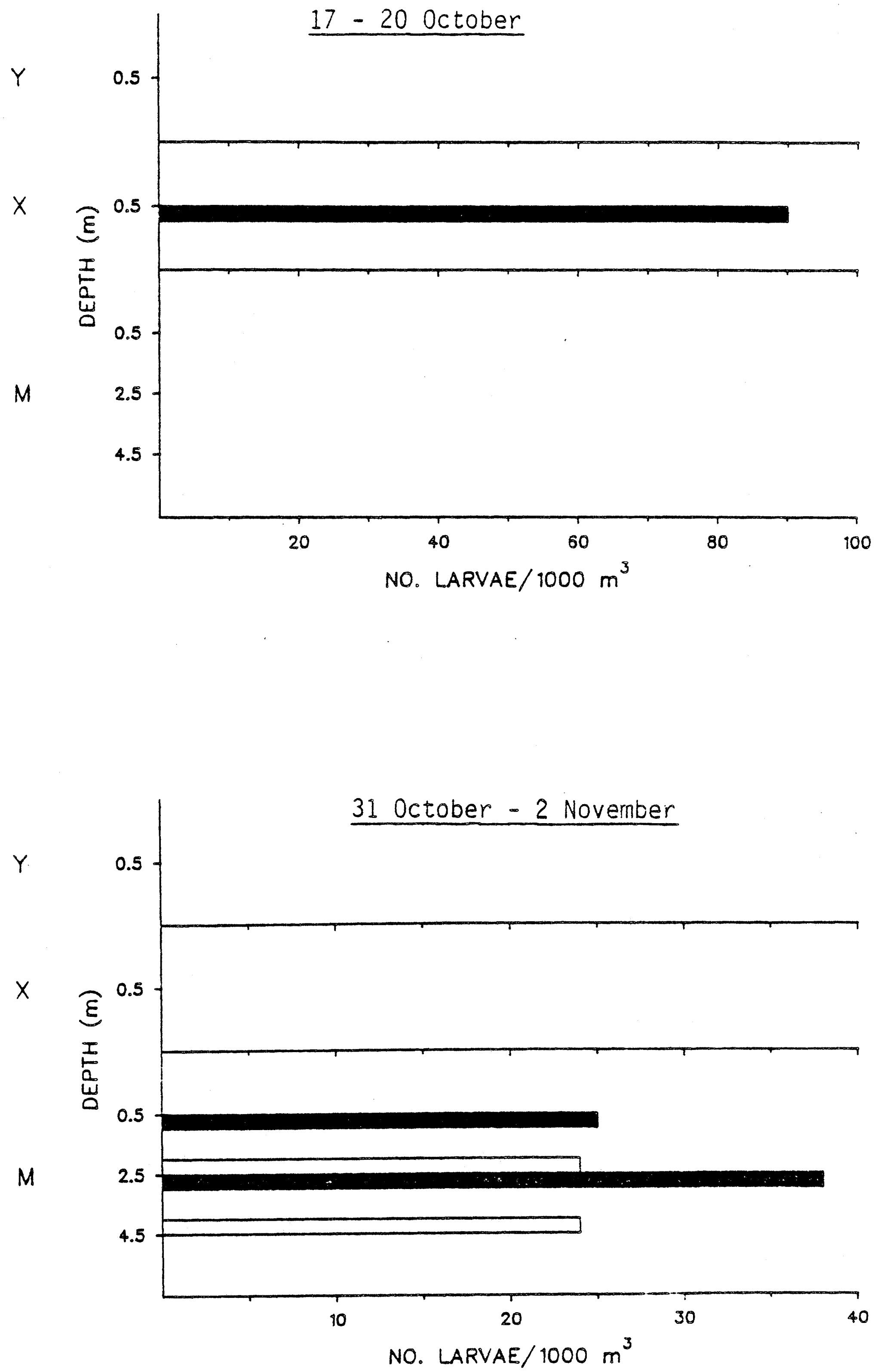


FIG. 87. Number of alewife larvae per 1000 m^3 for openwater Pigeon Lake stations near the J.H. Campbell Plant, eastern Lake Michigan, 1977. □ = Day ■ = Night

In December alewife fry concentrations of up to 19 /1000 m^3 were noted in Pigeon Lake, openwater station M (influenced by Lake Michigan). No other larvae or fry were collected. Only one station was sampled in Lake Michigan in December, station L (6 m - n.), no larvae were found.

Maximum entrainment losses of alewife larvae during the 1977 sampling period occurred in early July (Fig. 88). This period coincided with maximum densities of larvae observed at Lake Michigan stations. Alewife larvae entrainment was maintained at relatively high levels (greater than 0.4 million larvae/24 hr period) from 7 July through 10 August. The drastic decrease in alewife larvae entrained noted on 29 July was probably due to an upwelling which occurred at that time. Although post larvae and fry were entrained, newly hatched larvae seemed particularly susceptible to entrainment. Decreased numbers of alewife larvae entrained after 10 August was due to growth of larvae into the fry stage, as indicated by the increased number of fry entrained (Fig. 89). Peak numbers of fry entrained occurred in August, when most fry were small. Minimal entrainment of alewife larvae occurred after 19 September. No fry entrainment occurred from mid-November through December; which is probably indicative of alewife movement from the area.

Cyprinidae Complex

State of the art identification of cyprinid fish larvae is only now starting to address some of the problems in these areas. We have attempted to do our best in separating the various cyprinid larvae collected during sampling around the J. H. Campbell Plant using existing keys and literature, (some only now being published) and reference larvae from the Great Lakes Regional Fish Larvae Collection (GLRFLC) located at the Great Lakes Research Division Fisheries Laboratory. Because this was the first year of study and we had little experience working with many of the Pigeon Lake larval species, some compromises had to be made. The major species of cyprinid larvae (most numerous) were spottail shiners and bluntnose minnows. Less common species included golden shiner and carp. Other rarely caught cyprinids were: goldfish, emerald shiner, bigmouth shiner, blacknose shiner and longnose dace. When first picking samples and identifying larvae we established a special code (XM) to designate unknown cyprinid larvae. Many of the larvae collected from Pigeon Lake and some from Lake Michigan were called unknown cyprinids. To facilitate completion of this report, we reported these larvae as unknown cyprinids. However, we are in the process of developing the necessary expertise from newly published literature, GLRFLC and outside research scientists competent in this area, and we expect to re-identify as many unknown cyprinids as possible. Thus data presented for each of the known cyprinids in this section should be considered tentative, until a final determination about the identity of the unknown larvae is reached.

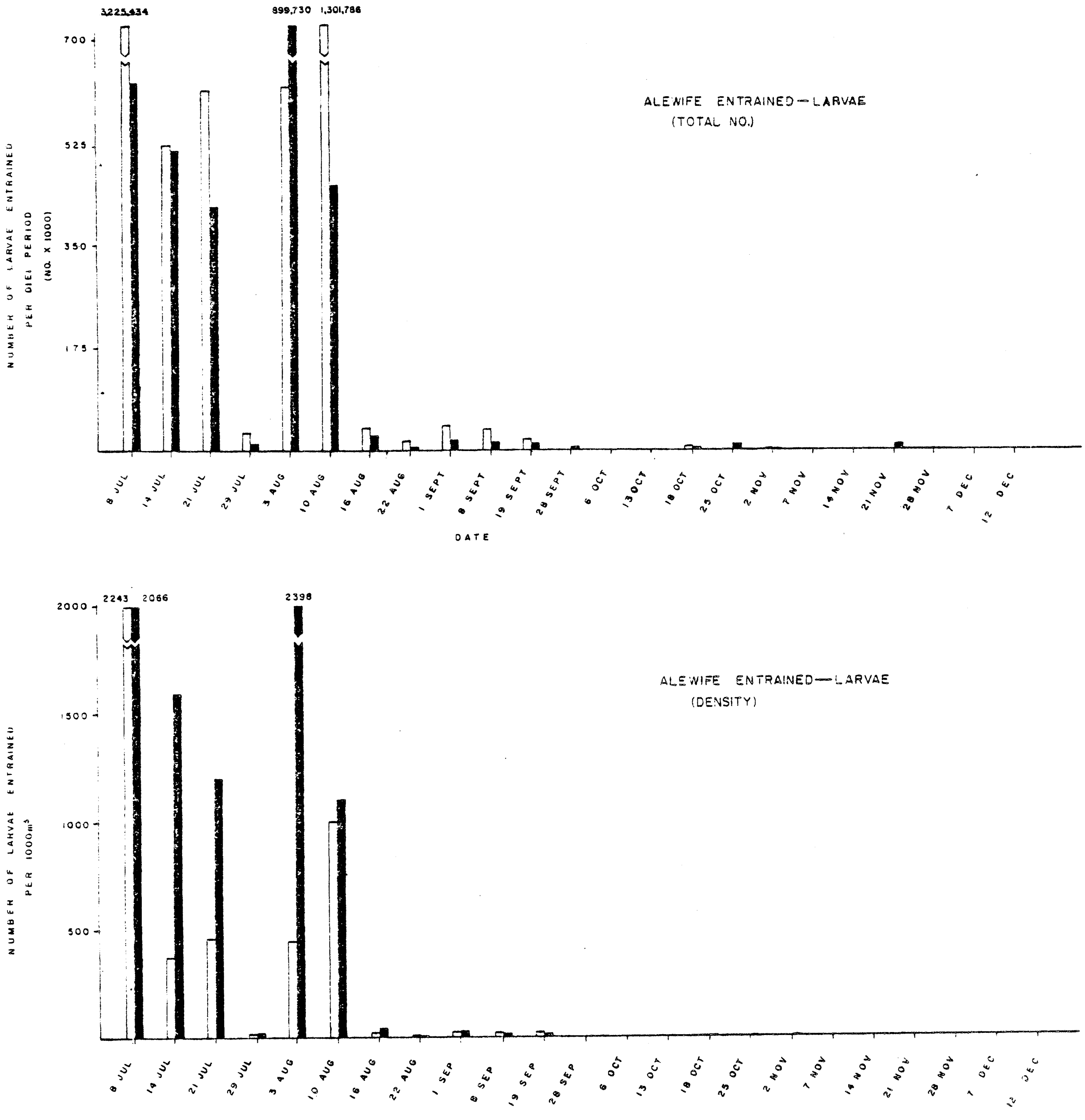


FIG. 88. Total number and density (No./1000 m^3) of larval alewife entrained during the day and night at the J. H. Campbell Plant, 1977. ☐ = Day ■ = Night

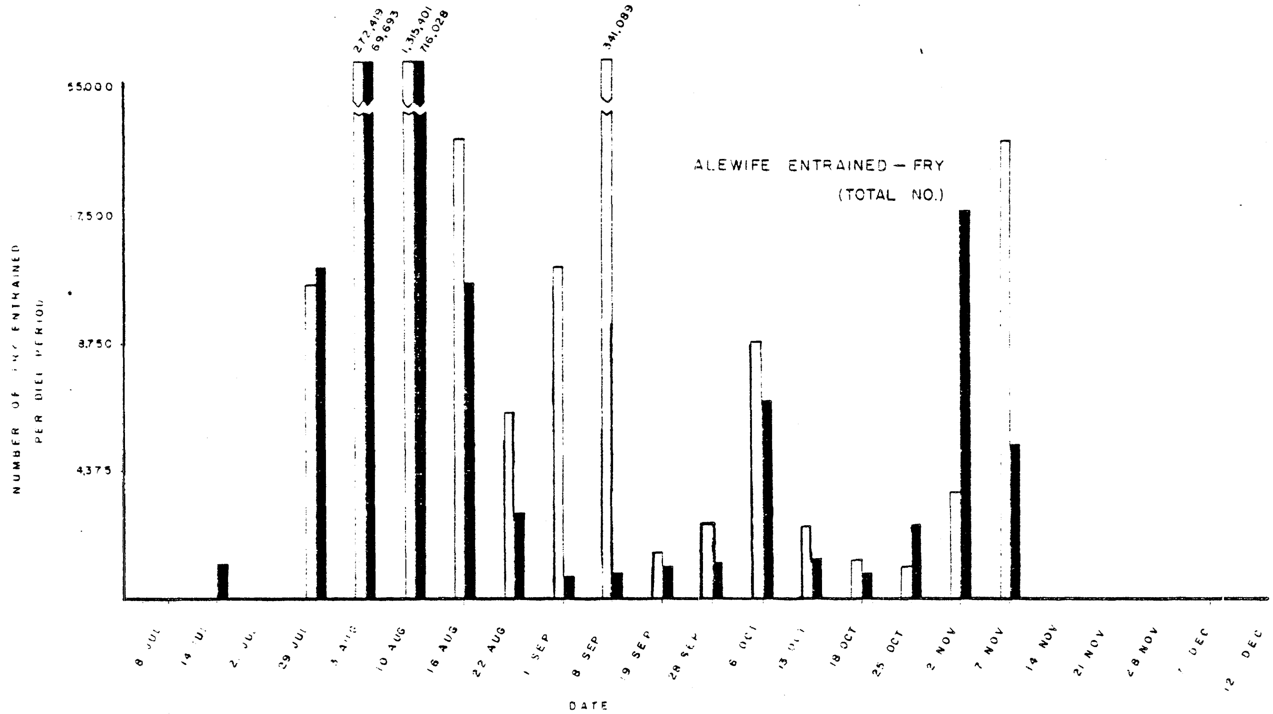


FIG. 89. Total number and density (No./1000 m^3) of alewife fry entrained during the day and night at the J.H. Campbell Plant, 1977.
□ = Day ■ = Night

Spottail Shiner--

The spottail shiner is the most abundant species of minnow in the Campbell Plant area. Large numbers have been observed in both Pigeon Lake and Lake Michigan, and an understanding of their larval distribution and seasonal abundance is paramount to gaining a full understanding of their role in each ecological system.

Spawning of spottail shiners occurred primarily in June and July in southeastern Lake Michigan during 1973-74 (Jude et al. 1979). Spawning occurs over sandy shoals (Scott and Crossman 1973), with spawning in clumps of algae also reported (Dorr and Miller 1975). Yearling spottails from Clear Lake, Iowa (70-90 mm) were reported to contain 100-1400 eggs, while 2-yr old specimens contained 1300-2600 eggs (McCann 1959).

Spottail shiner larvae were collected in the Campbell Plant area during our first sampling trip in early June. Lake Michigan beach

stations R (n. discharge) and Q (s. discharge) exhibited average densities of 146 and 73 larvae/1000 m^3 respectively (Fig. 90). These concentrations suggested the possibility that localized spawning in the immediate area of the present discharge, or possibly in the discharge canal itself, occurred in May. Average size of spottail shiner larvae for pooled Lake Michigan stations at this time was 4.9 mm (S.E. = 0.3 mm) (Fig. 91), indicating recent hatching as Dorr and Miller (1975) found newly hatched spottails from Lake Michigan to average 4.6 mm. Spawning beds of centrarchids were noted by Consumers Power plant personnel in the discharge canal, which indicated there were areas probably suitable for spawning of spottails there.

In contrast to the north transect, no spottail larvae were collected at the south transect in early June, indicating that spawning in May had apparently not occurred there. Water temperatures at south transect beach station P ranged from 9.5-13.0 C in early June, compared with temperatures of 8.0-17.0 C recorded at north beach stations at the time of larvae sampling.

Pigeon Lake samples from early June indicated that spottails also spawned there in May. High concentrations of spottail larvae were observed in Pigeon Lake samples in early June at beach stations T (influenced by Pigeon River) and S (influenced by Lake Michigan) with lower densities observed at station V (undisturbed Pigeon Lake) (Fig. 92). No spottail larvae were collected in the intake canal (station Z) in early June. All occurrences of spottail larvae during early June in both lakes, with the exception of those at beach station Q (s. discharge), were observed at night. General absence of spottail larvae in samples collected during the day may be due to net avoidance or the demersal character of this species during daylight hours which was noted by Jude et al. (1975); however, no sled tow samples were taken in June to verify this finding. Sled tow data from July and August however amply demonstrated the affinity of spottails for the bottom.

Late June sampling at Lake Michigan south transect stations showed no spottail larvae present. However, high densities of unidentified fish eggs were found (average 757 eggs/1000 m^3) at station P during the day which may indicate some spottail spawning at this time (Appendix 6). North beach stations Q (s. discharge) and R (n. discharge) continued to have concentrations of spottail larvae in late June comparable to early June (Fig. 90). Occurrence of eggs at north beach stations (up to 985 eggs/1000 m^3) (Appendix 7) may indicate continued spottail spawning in the area; some eggs may also be those of alewife. Water temperatures in late June ranged from 16.0-19.6 C at north beach stations and 16.0-17.5 C at south transect beach station P. Although water temperatures for both early and late June were not extremely different between north and south stations, there does appear to be significant differences in the spawning of spottails, with earlier spawning indicated at Lake Michigan

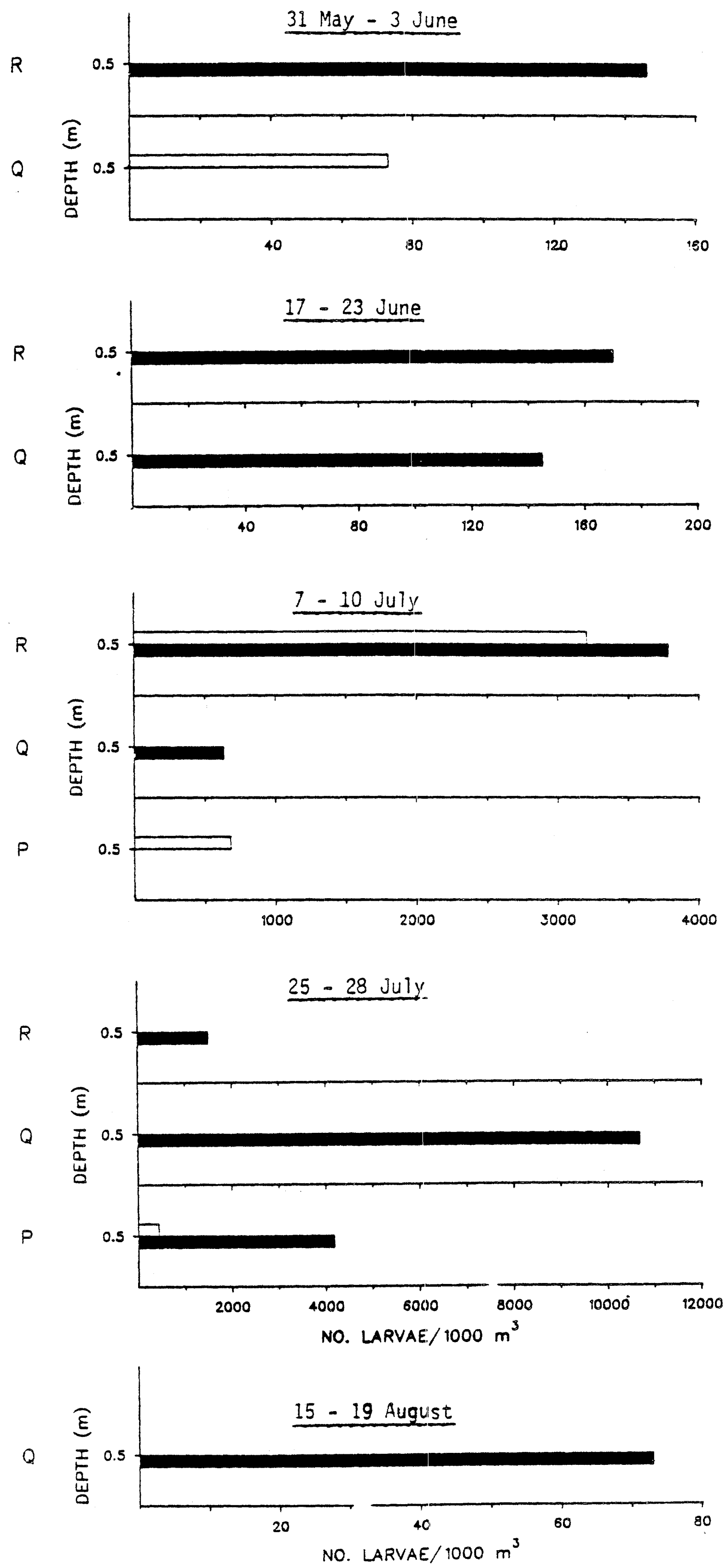


FIG. 90. Number of spottail shiner larvae per 1000 m^3 for Lake Michigan beach stations near the J. H. Campbell Plant, eastern Lake Michigan, 1977. ☐ = Day ■ = Night

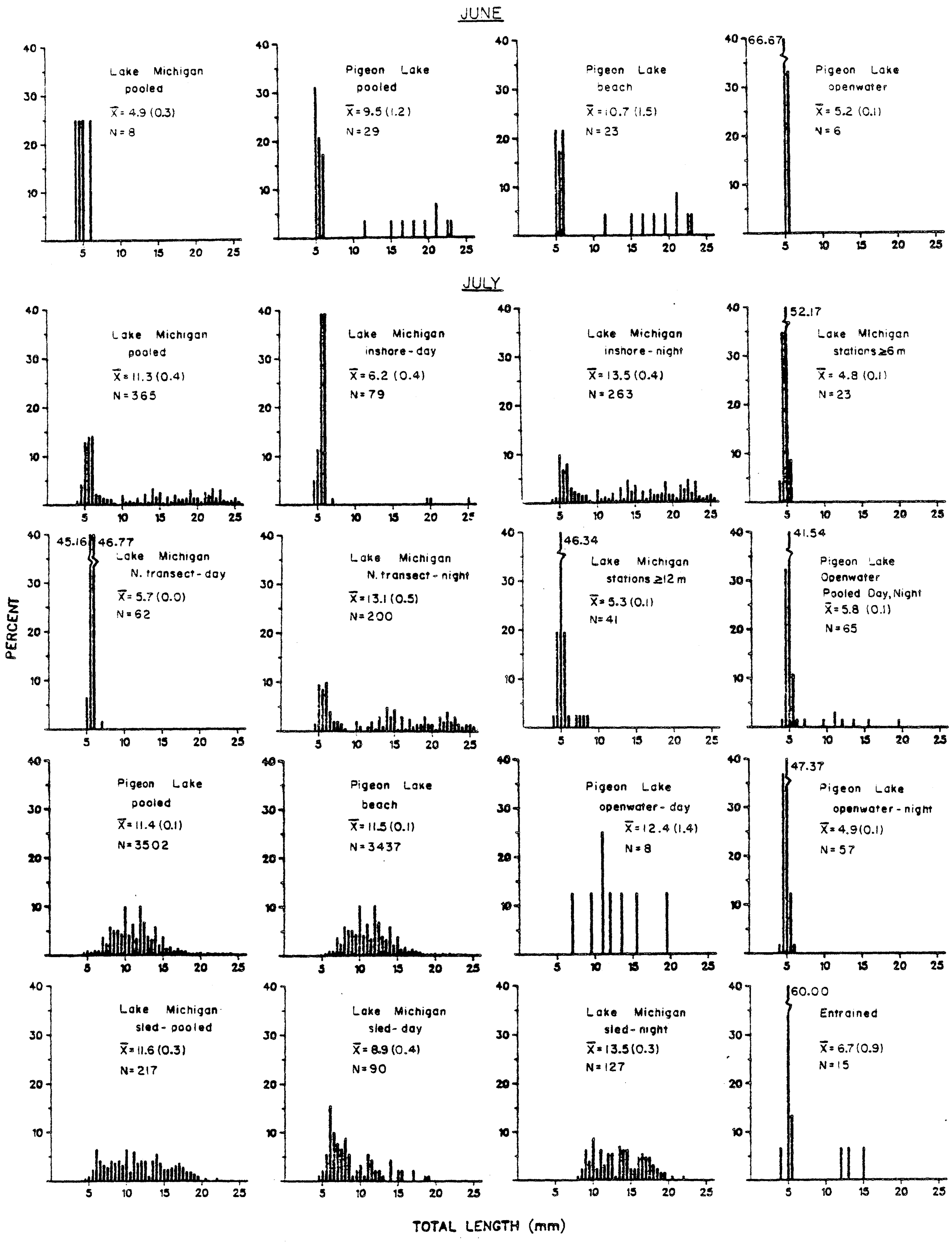


FIG. 91 . Length-frequency histogram for larval spottail shiner caught at selected pooled stations in Lake Michigan and Pigeon Lake near the J. H. Campbell Plant, 1977. All tows were net tows unless sled tows were specified. Inshore means all stations 3 m or less in depth ($\overline{X}$=mean, N= total number of larvae used in the comparison, standard error is given in parenthesis).

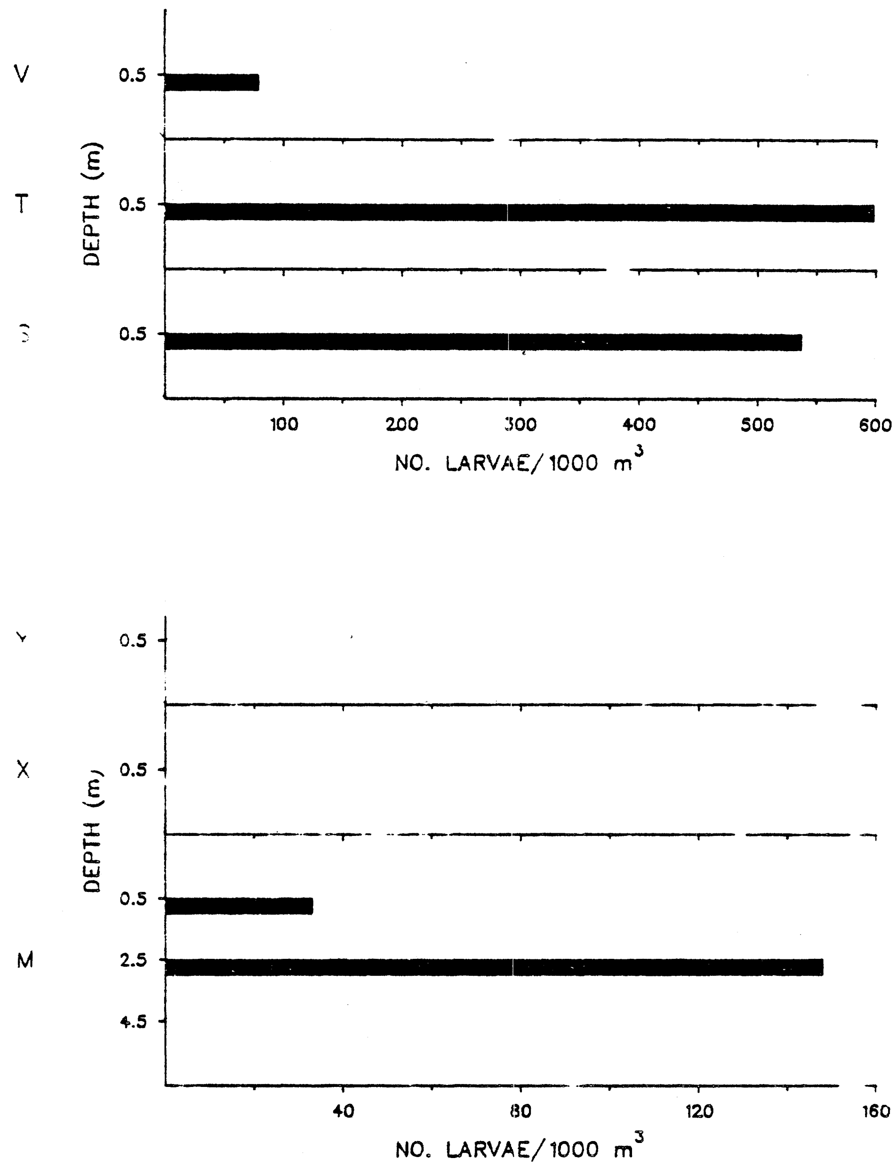


FIG. 92. Number of spottail shiner larvae per 1000 m^3 for beach and openwater stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan 31 May - 3 June 1977. □ = Day ■ = Night

north beach stations or in the discharge canal. Some spottail larvae (20 and 21 larvae/1000 m^3) were also noted at station L (6m - s.) at night on 17-23 June (Fig. 93).

In Pigeon Lake during late June, spottail larvae were noticeably absent from Lake Michigan influenced stations (S - beach and M - 6 m),

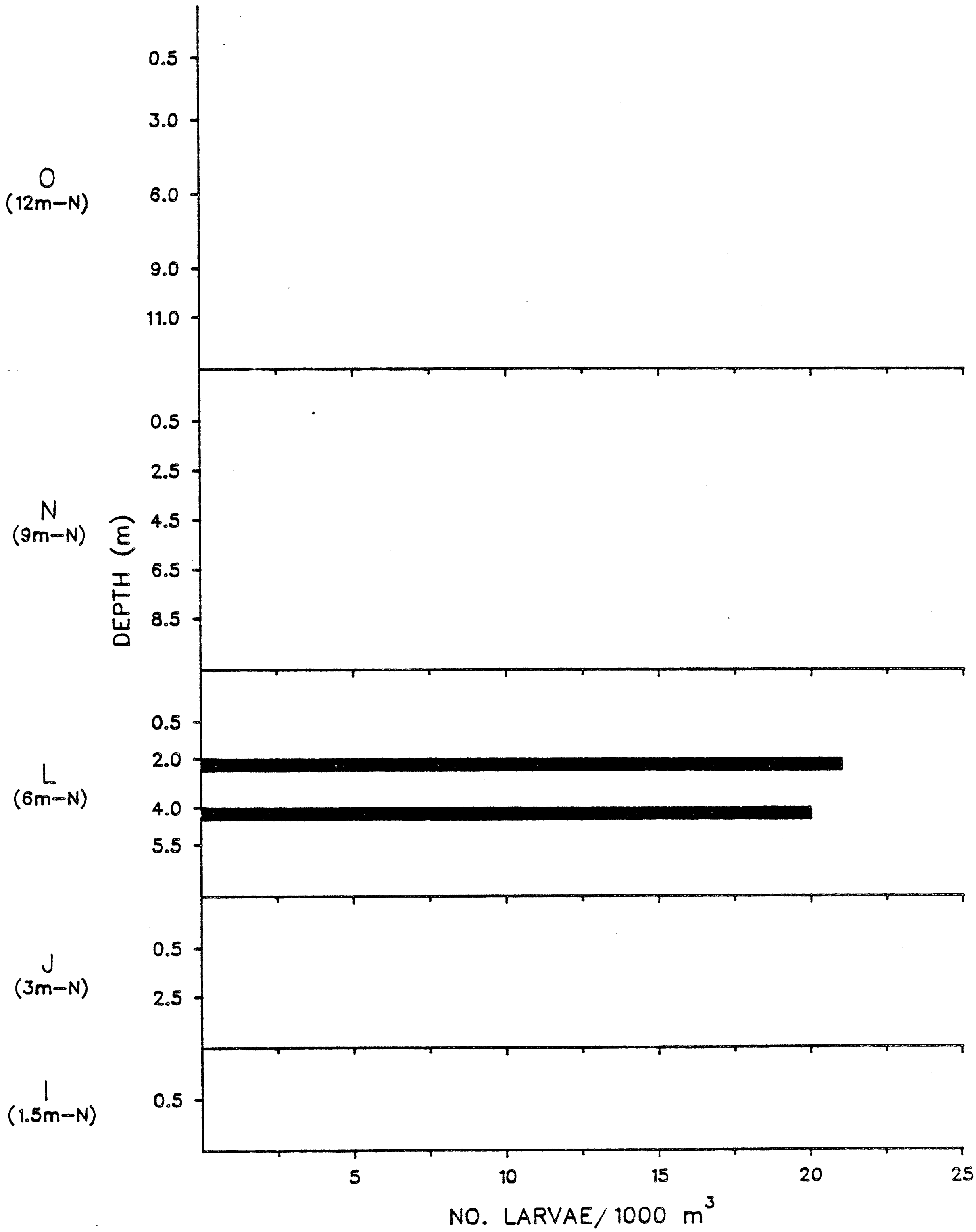


FIG. 93. Number of spottail shiner larvae per 1000 m^3 for north transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 17-23 June 1977. ☐ = Day ■ = Night

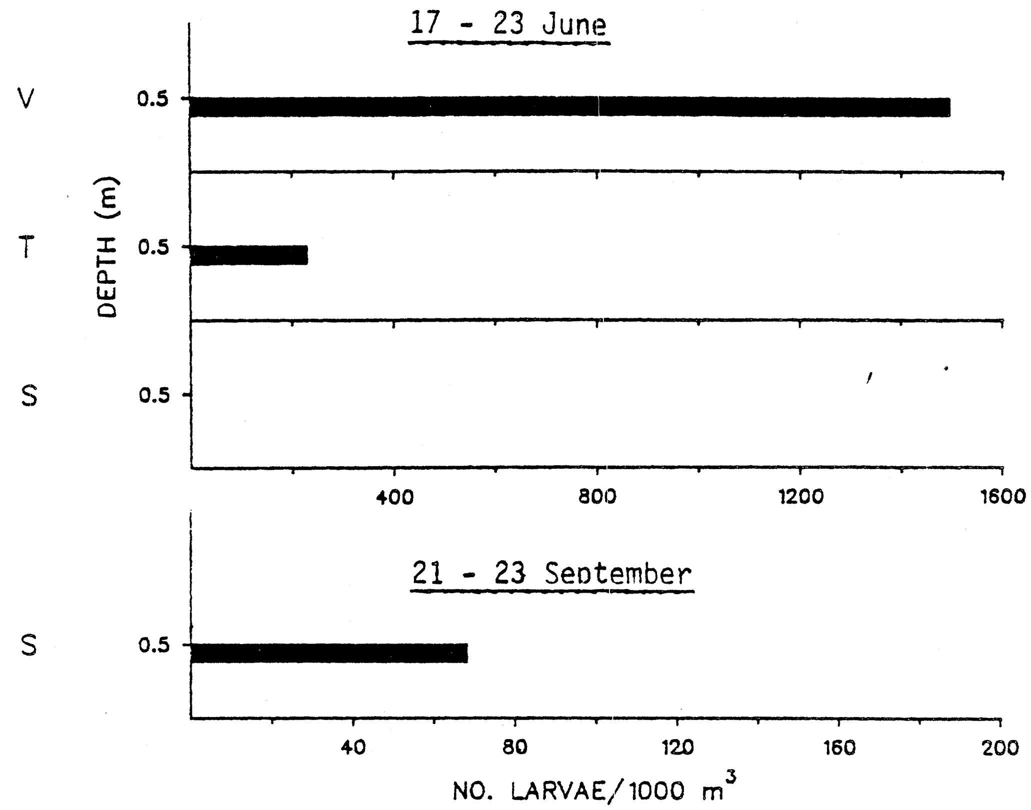


FIG. 94. Number of spottail shiner larvae per 1000 m^3 for beach stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 1977. □ = Day ■ = Night

as well as the intake canal (station Z) (Appendix 8). The reason for this may be related to water temperature. Temperatures in late June at Lake Michigan influenced stations ranged from 15.1-17.8 C, whereas Pigeon Lake beach stations T and V had temperatures from 20.0-24.4 C. Concurrently, these stations exhibited higher spottail larvae densities (Fig. 94). It is also possible that net avoidance may be a factor in the decreased catches observed in late June. While no larvae were found at beach station S (influenced by Lake Michigan) in late June, extremely high concentrations of eggs were found (15,306-18,190 eggs/1000 m^3), which may indicate spawning of spottails at this station had been at high levels in late June. High densities of eggs at station S in late June (Appendix 8) were coincident with high densities of eggs at Lake Michigan south beach station P (757 eggs/1000 m^3 found at night) (Appendix 6) and Lake Michigan north beach station Q (338 eggs/1000 m^3 reported at night). Although these occurrences of eggs may be signs of spottail spawning, some alewife spawning was also indicated.

Careful examination of length-frequency histograms for spottails caught during June (Fig. 91) showed that larvae collected in Lake

Michigan at this time (all pooled net tow samples) were around 4.5-6.0 mm; whereas, Pigeon Lake larvae pooled samples showed a length range much wider, from about 5 to 23 mm. This evidence was strong support for the two conclusions discussed previously: 1.) Recent spottail spawning had occurred in Lake Michigan, apparently in or around the discharge canal, which appeared to be initial spawning in this vicinity of Lake Michigan during 1977. This early spawning transpired in a localized area, no spawning apparently occurred at the south transect. 2.) The wide range of spottail lengths observed at Pigeon Lake stations indicated that spawning by spottail shiners occurred there much earlier (early May on) than spawning in Lake Michigan. Larvae caught at beach stations in Pigeon Lake exhibited a noticeably wider length interval than those smaller specimens caught in openwater samples (Fig. 91). This observation was partly the result of decreased net avoidance at beach stations (more vegetation) allowing larger larvae to be captured, but may also be indicative of the behavior of newly hatched larvae (which these were). Apparently some of these 1-3 day-old larvae were pelagic and planktonic, as indicated by their presence at these openwater stations. These data may also demonstrate a transfer of newly hatched spottail larvae from Lake Michigan and through Pigeon Lake in the cooling water utilized at the Campbell Plant.

Spottail larvae first occurred at Lake Michigan south transect stations in early July (Fig. 95), indicating spawning in this area occurred sometime in June. Spottail larvae at this time were distributed from the nearshore area station P (s. beach) (Fig. 90) to a depth of 12 m - s. station E (Fig. 95). There was a noticeable absence of spottail larvae at depths exceeding 12 m. Catches at openwater stations (B, 3 m - s. to E, 12 m - s.) were all at night, with a tendency of larvae to be found in deeper strata near bottom. An unusually high density of spottail larvae compared with openwater stations was noted at beach station P (s. reference) during the day (Fig. 90). Many larvae designated XM (unknown cyprinids-Appendix 7) at this time were probably spottail larvae, and hence would generate even higher night densities at beach stations.

North Lake Michigan stations in early July showed high densities of larvae present at beach stations Q (s. discharge) and R (n. discharge) (Fig. 90). Although highest concentrations there were observed at night, substantially high numbers were also found in day samples at station R. No larvae were found at openwater station L (6 m - n.) in early July.

High densities of spottail larvae were found at night in early July samples from Pigeon Lake at Lake Michigan influenced station M (6 m) and S (beach station) (Fig. 96). These high concentrations may indicate that peak spawning at beach station S (influenced by Lake Michigan) occurred coincidently with spawning of spottails in Lake Michigan. It

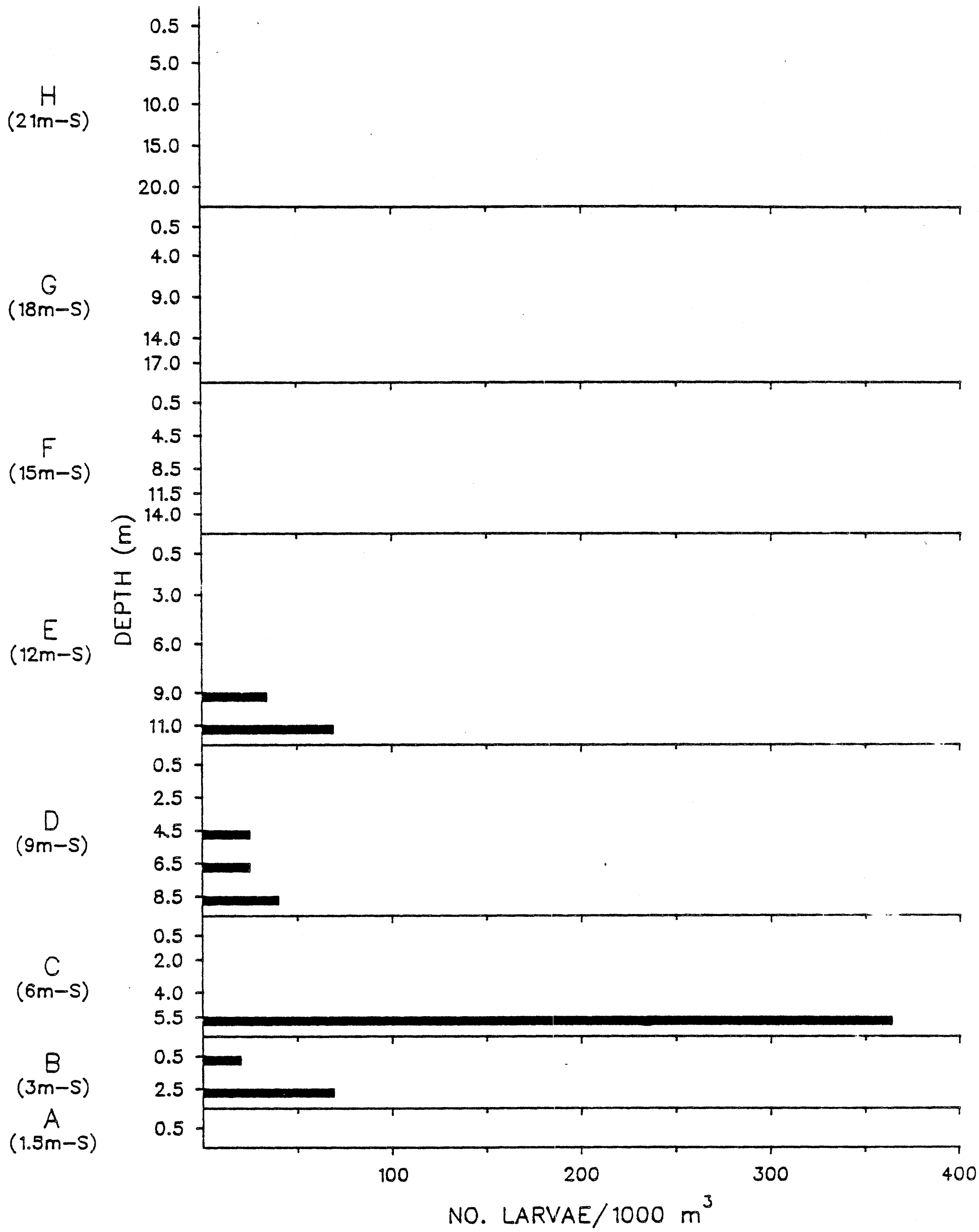


FIG. 95. Number of spottail shiner larvae per 1000 m^3 for south transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 7-10 July 1977. □ = Day ■ = Night

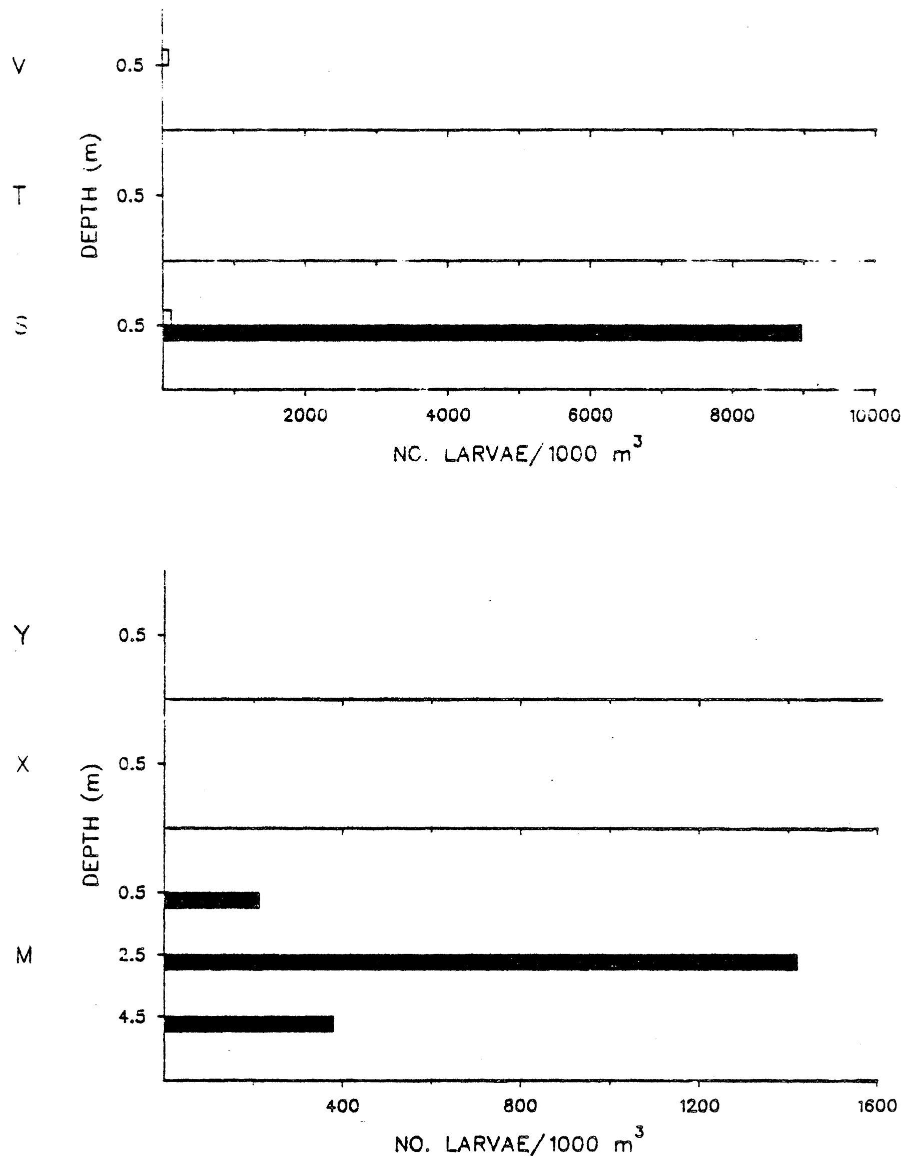


FIG. 96. Number of spottail shiner larvae per 1000 m^3 for beach and openwater stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 7 - 10 July 1977. □ = Day ■ = Night

is evident, however, that spawning of spottails did occur to some degree in May at this Pigeon Lake station. This earlier spawning was responsible for the densities of spottails at Lake Michigan influenced stations of Pigeon Lake in early June. There were no larvae found at station Z (intake canal) in early July.

In mid-July, only Lake Michigan north transect stations were

sampled. Spottail larvae were observed at this time at station I (1.5 m - n.) and J (3 m - n.) (Fig. 97). The higher density of spottail larvae at station I (1.5 m - n.), as well as lack of spottail larvae at depths 6-12 m, clearly demonstrated the tendency for larvae of this species to remain inshore. Sled tow samples taken on 20-21 July substantiated the contention. At south transect stations P (beach), A (1.5 m) and B (3 m) densities of spottail larvae ranged from 0 to 6791/1000 m^3 in sled tows (Appendix 9). Offshore south transect stations showed no spottail larvae present in sled tows with the exception of a low density of 49 larvae/1000 m^3 at station C (6 m). North transect stations showed a similar trend in sled tow samples with spottail larvae concentrations of 0-4431 larvae/1000 m^3 observed at Lake Michigan beach stations Q (s. discharge) and R (n. discharge) and station I (1.5 m - n.) (Appendix 9). No spottail larvae were observed deeper than 1.5 m on 20-21 July.

Late July Lake Michigan samples showed clearly that spottail larvae were inshore at depths less than 2 m. Lake Michigan south transect station P (beach) had densities from 435-4173 larvae/1000 m^3 (Fig. 90), while station A (1.5 m - s.) was the only offshore station with spottail larvae present (0-64 larvae/1000 m^3) (Fig. 98). This distribution pattern was consistent at the north transect, where spottail larvae were only collected at beach stations Q (s. discharge) and R (n. discharge) in concentrations ranging from 0-10,675 larvae/1000 m^3 (Fig. 90); none were found at offshore stations I (1.5 m) through O (12 m) (Appendix 7). An upwelling, which occurred during our sampling, apparently had little effect on spottail larvae distribution. Samples from Lake Michigan at this time also indicated that there were increased numbers of spottail larvae growing into the fry classification (Appendix 11).

Samples taken in Pigeon Lake in late July indicated extremely high densities of spottail larvae (13,978-283,674 larvae/1000 m^3) at beach station S (influenced by Lake Michigan) (Fig. 99), the highest concentration of spottail larvae we ever recorded. An overview of all monthly data suggested that these high densities in late July merely reflected extensive use of this Pigeon Lake habitat as a nursery area for spottail shiners. Beach station S may be selected for spawning by spottail over other Pigeon Lake beach stations due to its sandy bottom and moderate vegetation. Some spottail larvae were also observed at station M (6 m-Pigeon Lake) at the surface (100 larvae/1000 m^3) and 2.5 m depth (94 larvae/1000 m^3) in late July (Fig. 99). No spottail larvae were observed at station Z (intake canal) in late July.

Length-frequency comparisons of Pigeon Lake spottail larvae collected in July (Fig. 91) indicated larvae at openwater stations M (6 m), X (1.5 m) and Y (1 m) were smaller ($\bar{x}$ = 5.8 mm S.E. = 0.1) than those collected at beach stations S (influenced by Lake Michigan), V (undisturbed Pigeon Lake) and T (influenced by Pigeon River) ($\bar{x}$ = 11.5 mm) S.E. = 0.1. This may indicate that some small spottail larvae

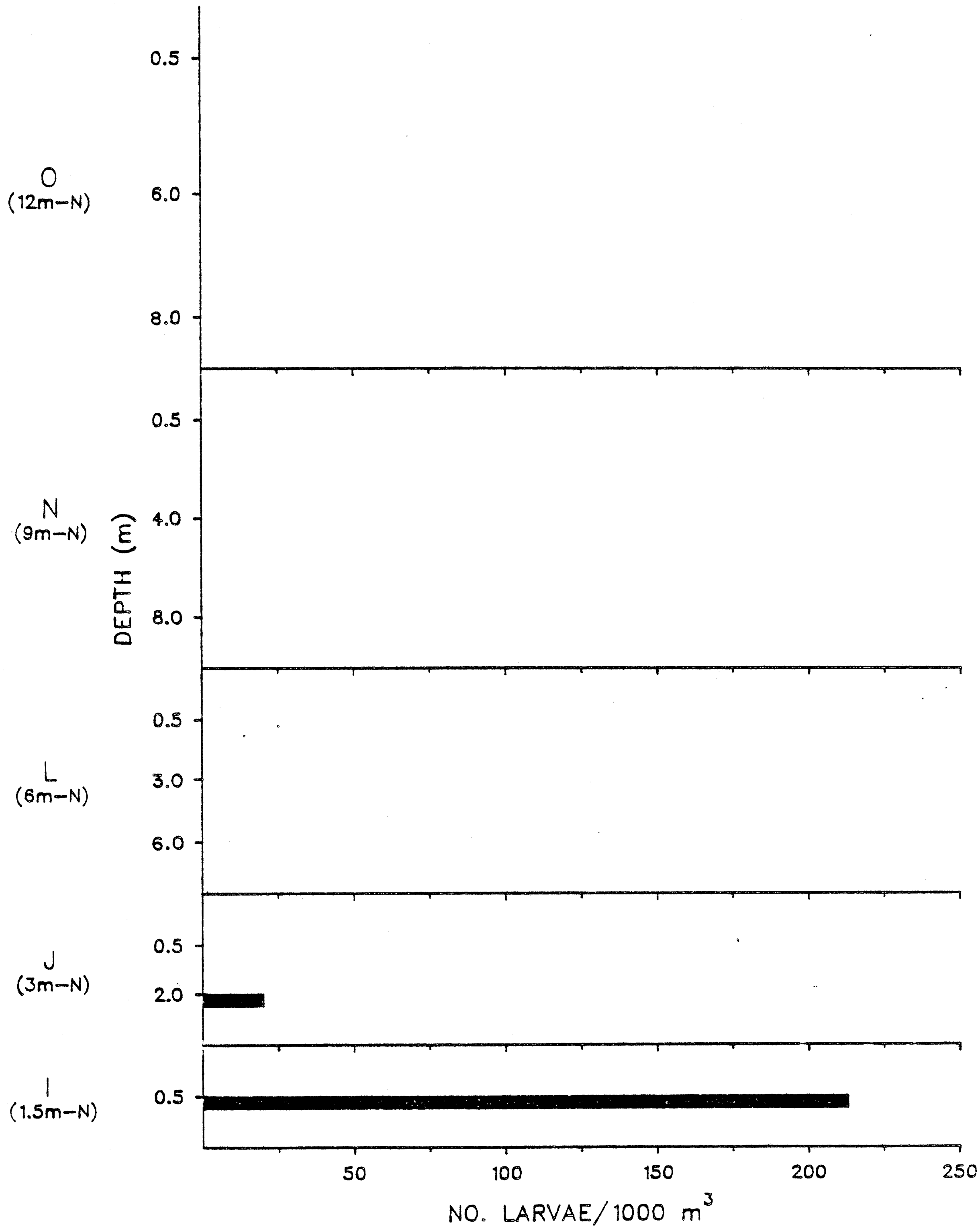


FIG. 97. Number of spottail shiner larvae per 1000 m^3 for north transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 13 July 1977. ☐ = Day ■ = Night

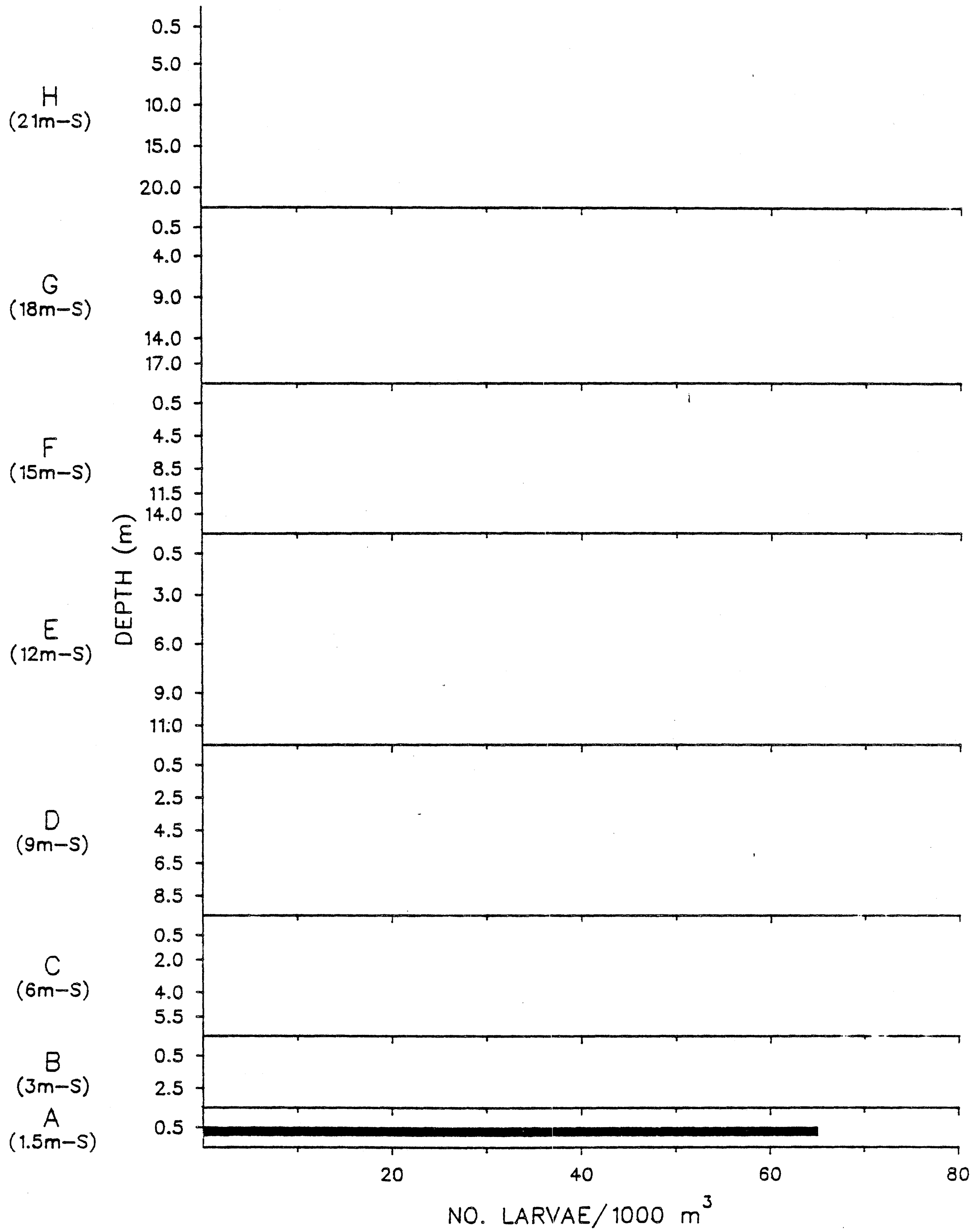


FIG. 98. Number of spottail shiner larvae per 1000 m^3 for south transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 25-28 July 1977. □ = Day ■ = Night

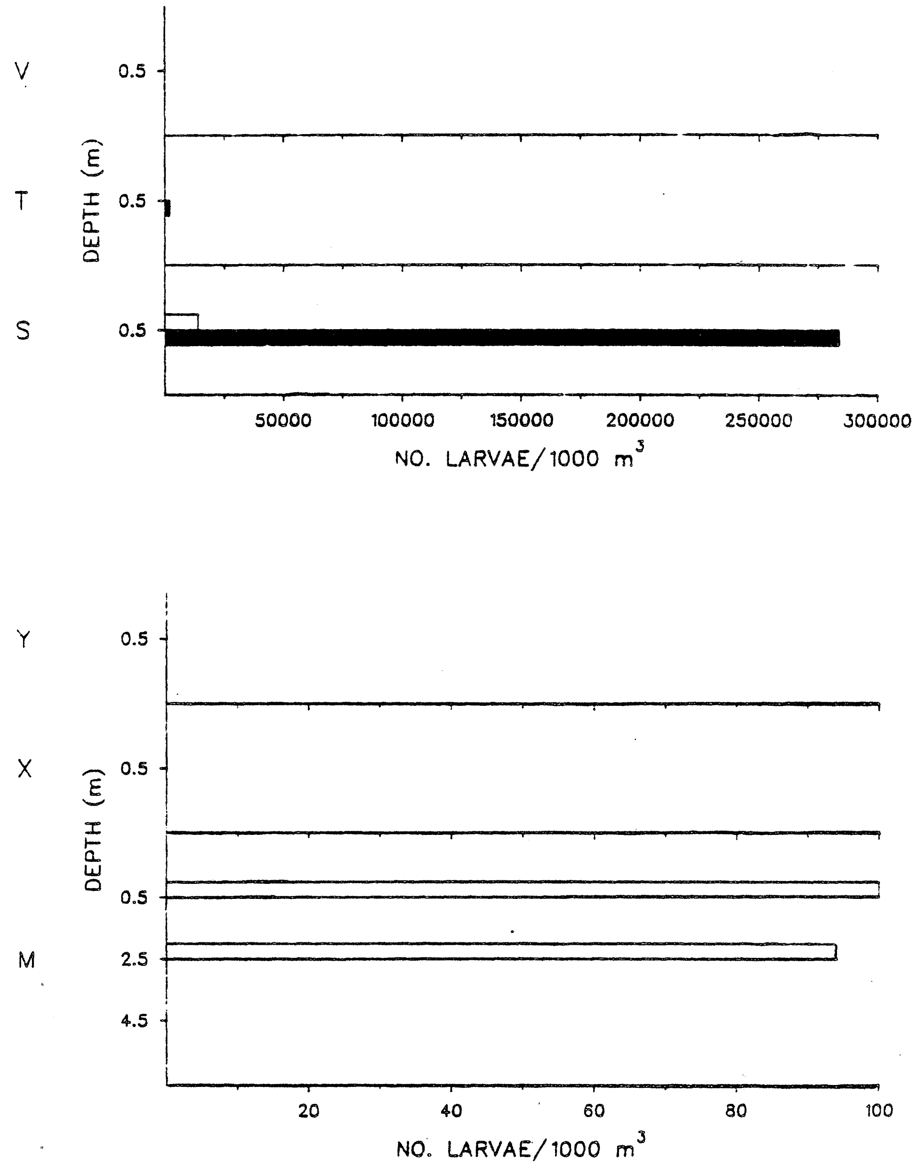


FIG. 99. Number of spottail shiner larvae per 1000 m^3 for beach and openwater stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 25 - 28 July 1977. □ = Day ■ = Night

were subject to currents which drew larvae away from shore areas.

Recall that a similar phenomenon, where many newly hatched spottail larvae were found in openwater while a much wider length range of larvae occurred at beach stations, was also found during June in Pigeon Lake. Presence of vegetation at beach stations may increase the efficiency of our nets there. Day-night differences in length of larvae captured was

also dramatic at openwater Pigeon lake samples in July. During the day, many large larvae were captured, while at night, only newly hatched larvae were collected. Apparently the longer spottails (at least some), were in surface waters during the day (possibly feeding) while at night they were either demersal in their distribution or moved inshore to littoral zone stations. Comparing Pigeon Lake pooled samples (N=3502) with Lake Michigan pooled samples for July (N=365) (Fig. 91), showed that spottails were collected in higher densities and more often in Pigeon Lake, with the length range of spottails from both habitats comparable. Spottails from Pigeon Lake, which undoubtedly were spawned earlier than Lake Michigan specimens, appeared in Pigeon Lake beach seine catches in July as YOY with a modal length of 40 mm (Appendix 5). Many other YOY 25-30 mm were also captured. In contrast, Lake Michigan seine catches in July contained very few individuals that were 20-40 mm. Large numbers of YOY from Lake Michigan seine catches were present in the 30 and 40 mm length interval during August, almost a month behind the YOY modal length group of spottails in Pigeon Lake. YOY distribution differences between Pigeon Lake and Lake Michigan are also discussed under JUVENILE and ADULT FISH-Spottail Shiner.

Lake Michigan length-frequency data for spottail shiners caught during July (Fig. 91) showed that by this time a full length range of larvae (4.5-25 mm) was present. Breaking down the Lake Michigan stations by depth showed the predominance of spottails in the inshore (3 m, 1.5 m and beach zone) water. Day-caught spottails inshore ranged in length from about 4.5-25 mm with a mean of 6.2 mm (S.E. = 0.4, N = 79), while night-caught larvae, though having a similar range, were more abundant and on the average twice as long, with a mean of 13.5 mm (S.E. 0.4, N = 263). Stations in Lake Michigan 6 to 12 m had some spottails present; but most were small, from 4.5-7 mm, suggesting that some of the main population of larval spottails were transported offshore during their early existence.

A classic example of net avoidance was provided by comparing the north transect stations day catch with the night catch (Fig. 91). Sixty-two larvae (5-7 mm long) with a mean length of 5.7 mm (S.E. = <0.1) were caught during the day; at night 200 (4.5-25.4 mm long) with a mean length of 13.1 mm (S.E. = 0.5) were collected.

Sled tow length-frequency data also aptly demonstrated the inshore distribution of spottails as well as the phenomenon of net avoidance (Fig. 91). From day sled tows in Lake Michigan, 90 larvae with a mean length of 8.9 mm (S.E. = 0.4, range 4.5-18 mm) were found; at night there was a drastic shift to more and larger sizes of larvae, when 127 with a mean of about 13.5 mm (S.E. = 0.3, range 8-22 mm) were observed.

During July, densities of spottail larvae in entrained water did not exceed 21 larvae/1000 m^3. Despite the wide availability of many

sizes of larvae in both Pigeon Lake and Lake Michigan, and a tendency for the newly hatched spottails to be planktonic and therefore susceptible to entrainment, few were entrained. Lengths of entrained larvae appeared in two distinct size groups, one in the newly hatched range around 5 mm, and another around 14 mm (Fig. 91).

August collection of spottail larvae from Lake Michigan was restricted to north beach station Q where 190 larvae/1000 m^3 were observed in a sled tow sample, and station I (1.5 m - n.) where 39 larvae/1000 m^3 were observed. Lack of spottail larvae in Lake Michigan samples in August was probably due to net avoidance, as well as growth of many larvae into "fry" stage. August beach seine data from Lake Michigan (Fig. 20) as previously discussed, documented presence of many YOY in the 30-40 mm intervals. Pigeon Lake beach station S continued to have high densities of spottail larvae (Fig. 100) indicating its continued use as a rearing area. Lower densities of spottail larvae were observed at station V in August.

During August as with all prior months, more spottail larvae were caught in Pigeon Lake (1960) than in Lake Michigan (1), despite peak abundance in Lake Michigan during July. In Pigeon Lake, another good example of net avoidance was shown with the pooled beach length-frequency samples, where during the day the distribution was skewed to the left (mean of 14.9 mm S.E. = 0.1) while at night longer larvae were caught which skewed the distribution to the right (mean of about 19.2 mm, S.E. = 0.2) (Fig. 101). Pooled sled tows in August (all larvae were caught during the day) showed a wide length range (5-22 mm) of spottails present in Lake Michigan. Entrained larvae apparently came from Pigeon Lake, as few were observed in Lake Michigan; whereas, many were found at Pigeon Lake stations. Entrained larvae in August (N = 18) ranged in length from 10-22 mm with a mean of 15.5 mm.

Spottail larvae were absent from Lake Michigan samples collected during September-November, which may be attributed primarily to larval growth. Spottail fry occurrence in plankton nets was sporadic in September at Lake Michigan inshore stations (Appendix 11); none were found in October and November samples from Lake Michigan.

Spottail densities of 69 larvae/1000 m^3 were still observed at Pigeon Lake beach station S in September at night. No larvae were observed during the day at this station (Fig. 94). This decrease in concentration compared with August was probably due to larval growth to the fry stage (2327 YOY spottails 30-50 mm were seined in September) (Appendix 5). No spottail larvae were found at other Pigeon Lake stations in September. Spottail larvae were also absent from all October through December Pigeon Lake samples.

In general, spottail larvae were not very susceptible to

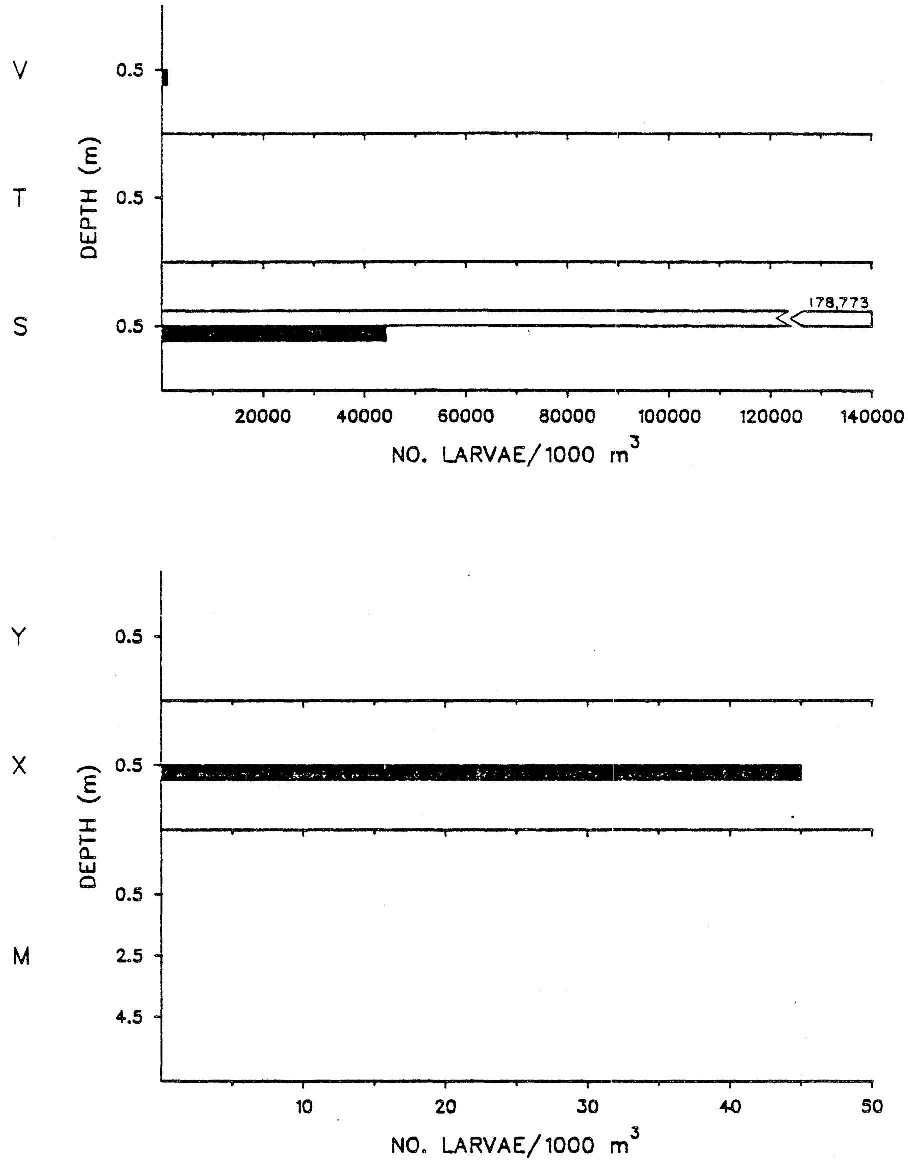


FIG. 100. Number of spottail shiner larvae per 1000 m^3 for beach and openwater stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 15-19 August 1977.
□ = Day ■ = Night

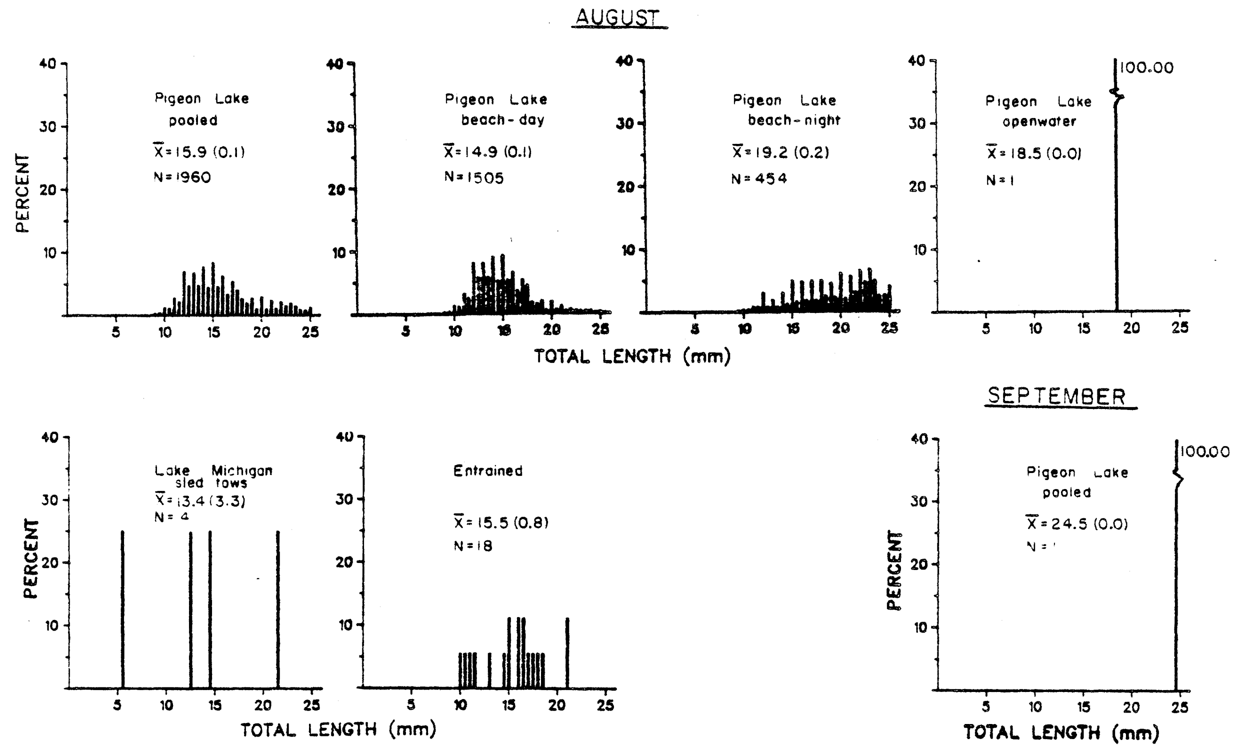


FIG. 101. . Length-frequency histogram for larval spottail shiner caught at selected pooled stations in Lake Michigan and Pigeon Lake near the J.H. Campbell Plant, 1977. All tows were net tows unless sled tows were specified. ($\bar{X}$=mean, N=total number of larvae used in the comparison, standard error is given in parenthesis.)

entrainment through the Campbell Plant. Entrainment of this species only occurred in July and August almost exclusively at night, and all observations indicated low densities (25 larvae/1000 m^3) of spottail larvae (Fig. 102). Highest concentrations of spottail larvae observed at the 6 m openwater station M in Pigeon Lake in early July night samples (213-1418 larvae/1000 m^3) coincided with observations of only 17 larvae/1000 m^3 in discharged water (Appendix 10) , indicating that most of the small larvae (about 6 mm) observed at station M in July were somehow avoiding the intake current. Lack of spottail larvae at station Z (intake) during all months sampled also substantiated this. Spottail shiner fry were entrained from one to five times per month during July to November in concentrations ranging from 8-19/1000 m^3 (Appendix 11).

The reason for such low entrainment of spottail larvae and fry was probably related to the tendency of this species to be demersal during the day. Field samples indicated that this species was sometimes found in the upper strata of the water column at night. Seven of the nine occurrences of entrainment of spottail larvae and ten of twelve occurrences of fry occurred at night, indicating that this species was

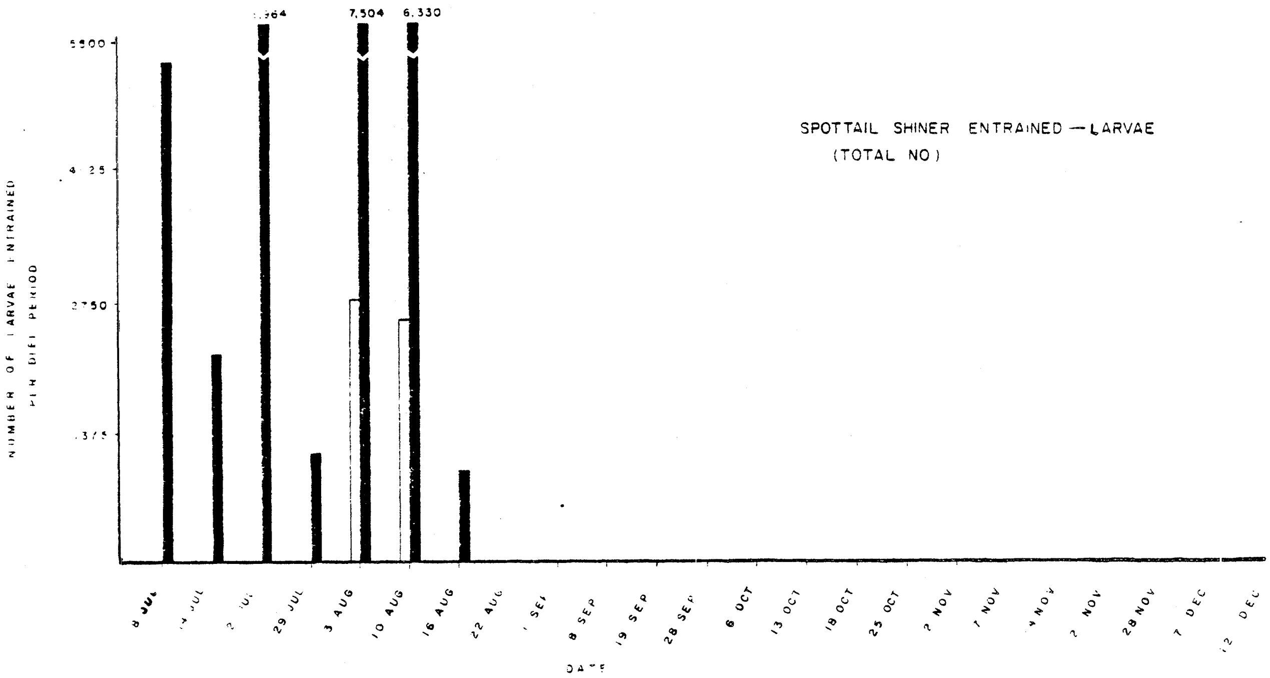


FIG. 102. Total number of larval spottail shiner entrained during the day and night at the J. H. Campbell Plant, 1977.

□ = Day ■ = Night

probably more vulnerable to entrainment when it entered upper water strata at night.

Bluntnose Minnow --

The bluntnose minnow, a likely candidate for the unknown cyprinid larvae category, was another species in the Cyprinidae complex found in Pigeon Lake. Adult bluntnose comprised about 7.5% of the total number of adult fish caught in Pigeon Lake, making them an important species numerically. Like the adults, all bluntnose larvae were taken at Pigeon Lake beach stations. In the early June sampling period, bluntnose larvae were recorded at night at beach station T (influenced by Pigeon River) at a density of about 250 larvae/1000 m^3 (Fig. 103). Bluntnose larvae caught in June were quite long, from 15 to 22 mm (Fig. 104) indicating much earlier spawning, perhaps late April-early May. The bluntnose adult fish discussion corroborates this estimation.

In July, bluntnose larvae were observed at beach station V (undisturbed Pigeon Lake) at night (1075/1000 m^3) and at station S (influenced by Lake Michigan) during the day; the average concentration

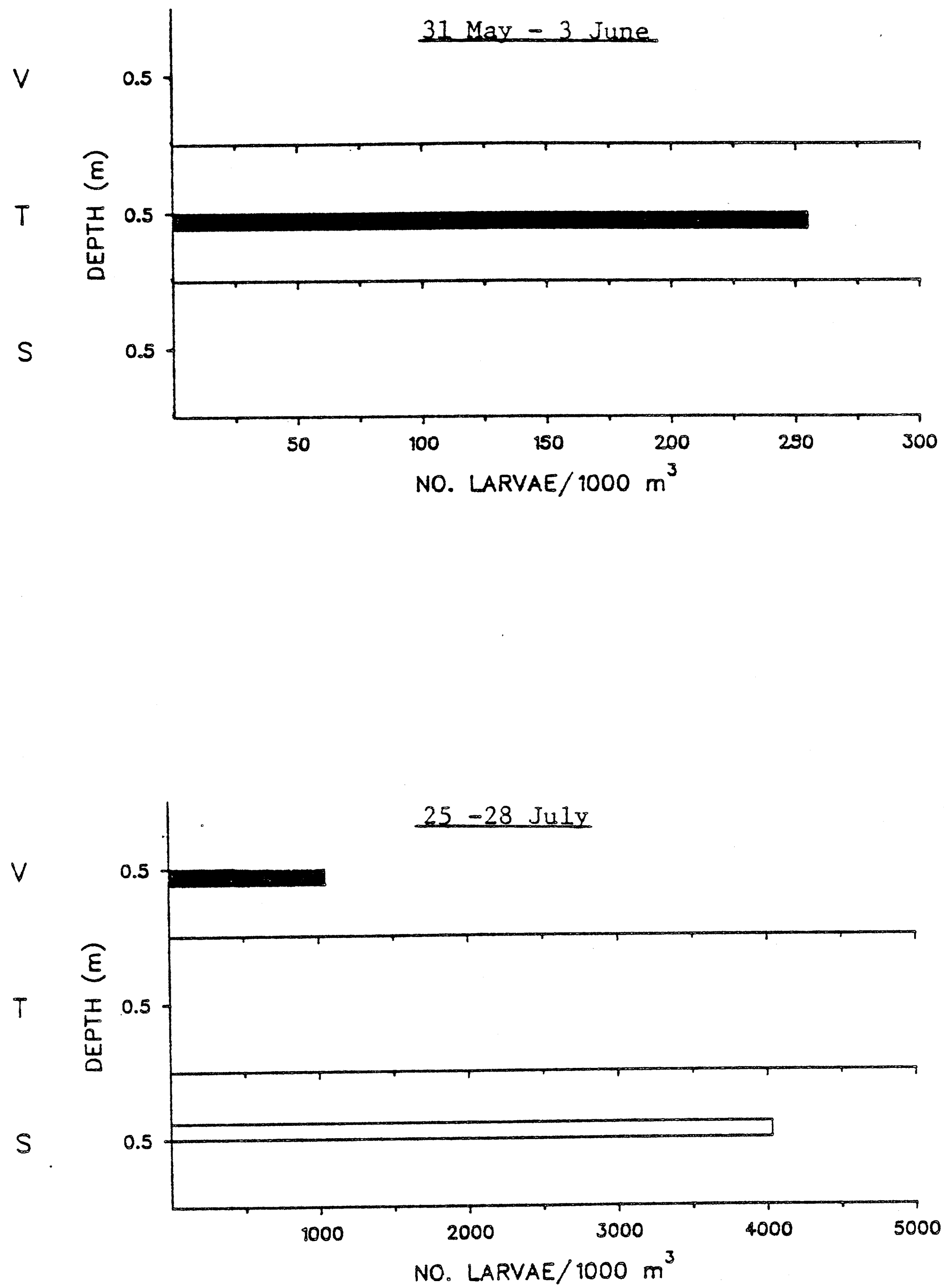


FIG. 103. Number of bluntnose minnow larvae per 1000 m^3 for beach stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 1977. □ = Day ■ = Night

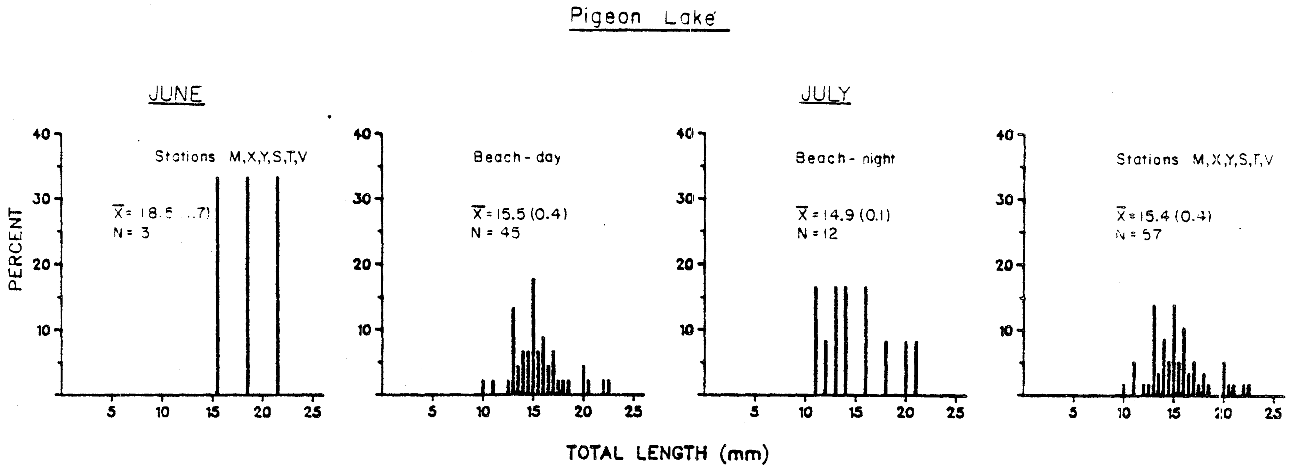


FIG. 104. Length-frequency histogram for larval bluntnose minnow caught at selected pooled stations in Lake Michigan and Pigeon Lake near the J.H. Campbell Plant, 1977. All tows were net tows unless sled tows were specified. ($\bar{X}$=mean, N=total number of larvae used in the comparison, standard error is given in parenthesis.)

of larvae was 4032/1000 m^3(Fig. 103). Contrary to expectations, more larvae were caught during the day and approximately the same length groups (10-23 mm) were sampled both day and night at Pigeon Lake beach stations (Fig. 104). Apparently net avoidance was minimal over diel period which was certainly possible since all larvae came from beach stations in Pigeon Lake. Beach stations had maximum macrophyte density in July, which undoubtedly reduced the ability of larvae to detect a moving net.

No bluntnose minnows were identified in entrainment samples (Appendix 10). If unknown cyprinids really were bluntnose minnows as we suspect, it will be difficult to use the technique of examining larger specimens and working backwards to the unknown smaller size, because very few unknown cyprinids and no bluntnose were entrained in later months. The only cyprinids that were identified from entrainment samples, all in low abundance, were spottail and emerald shiners. Further sampling near the plant as well as more work on the cyprinid complex should solve this problem.

Golden Shiner--

Golden shiner adults comprised almost 13% (2615 fish) of the total catch of fish from Pigeon Lake; they were the third most abundant fish collected following alewife and spottail shiner. Despite this abundance very few larvae were collected, which may of course be related to the problems of identifying cyprinids. Some percentage of the unknown

cyprinids were probably golden shiners.

All identified golden shiner larvae were collected during June and July in Pigeon Lake at beach stations S (influenced by Lake Michigan) and T (influenced by Pigeon River) (Fig. 105). Larvae captured during early June at station T ranged in length from 7.5 to 20 mm and were taken in concentrations from 85 to 651/1000 m^3. During the 17-23 June period golden shiner larvae (690/1000 m^3) were only captured at night at station T (Appendix 8).

During the late July period, golden shiner larvae captured were still small, from 9 to 16 mm in length, and were taken exclusively at station S at night; density of larvae was 807/1000 m^3. It is obvious from these data that golden shiner larvae preferred beach zone littoral areas, as they were never collected at openwater stations in Pigeon Lake or anywhere in Lake Michigan. In addition, no identified golden shiners were entrained during July-December 1977.

Golden shiner fry were observed six times in net tows during the study. They were taken at night at station T on 23 June, 7 July, 26 July and 16 August (Appendix 11), reaffirming their occurrence at well-vegetated littoral-zone beach stations. The reason for fry being caught only at night at station T was undoubtedly related to the dense macrophytes and turbid water present at this remote section of Pigeon Lake near the confluence with the Pigeon River.

Carp--

Carp larvae were collected from both Lake Michigan (11) and Pigeon Lake (18) mostly in July but one was also taken in June. In addition 18 were observed in entrainment samples during July. The 23 June specimen (7.0 mm long) was taken in a night surface sample at openwater station X (undisturbed Pigeon Lake) (Fig. 106). Water temperature was 18.5 C.

On 7 July, five carp larvae (6.0-8.5 mm long) were collected in night surface samples at beach station V (undisturbed Pigeon Lake) (Fig. 107) giving a larval density of 657/1000 m^3. Three larvae (4.5-6.5 mm) were also taken at Pigeon Lake openwater station M (influenced by Lake Michigan). On 25-28 July, three larvae (6.5-11.0 mm) were taken in a night surface sample from Pigeon Lake beach station S (influenced by Lake Michigan), yielding a larval density of 269/1000 m^3 (Fig. 106). Six larvae (9.5-23.5 mm) were also collected in replicate night surface samples at beach station V. Larval density was 538/1000 m^3.

In Lake Michigan on 7 July four carp larvae (5.0-6.0 mm) were collected at beach station R (n. discharge); larval density was 296/1000 m^3 (Fig. 108). On 9 July one larva was collected from each of three Lake Michigan stations: a 6 m night sample at 9 m station D (5.0 mm

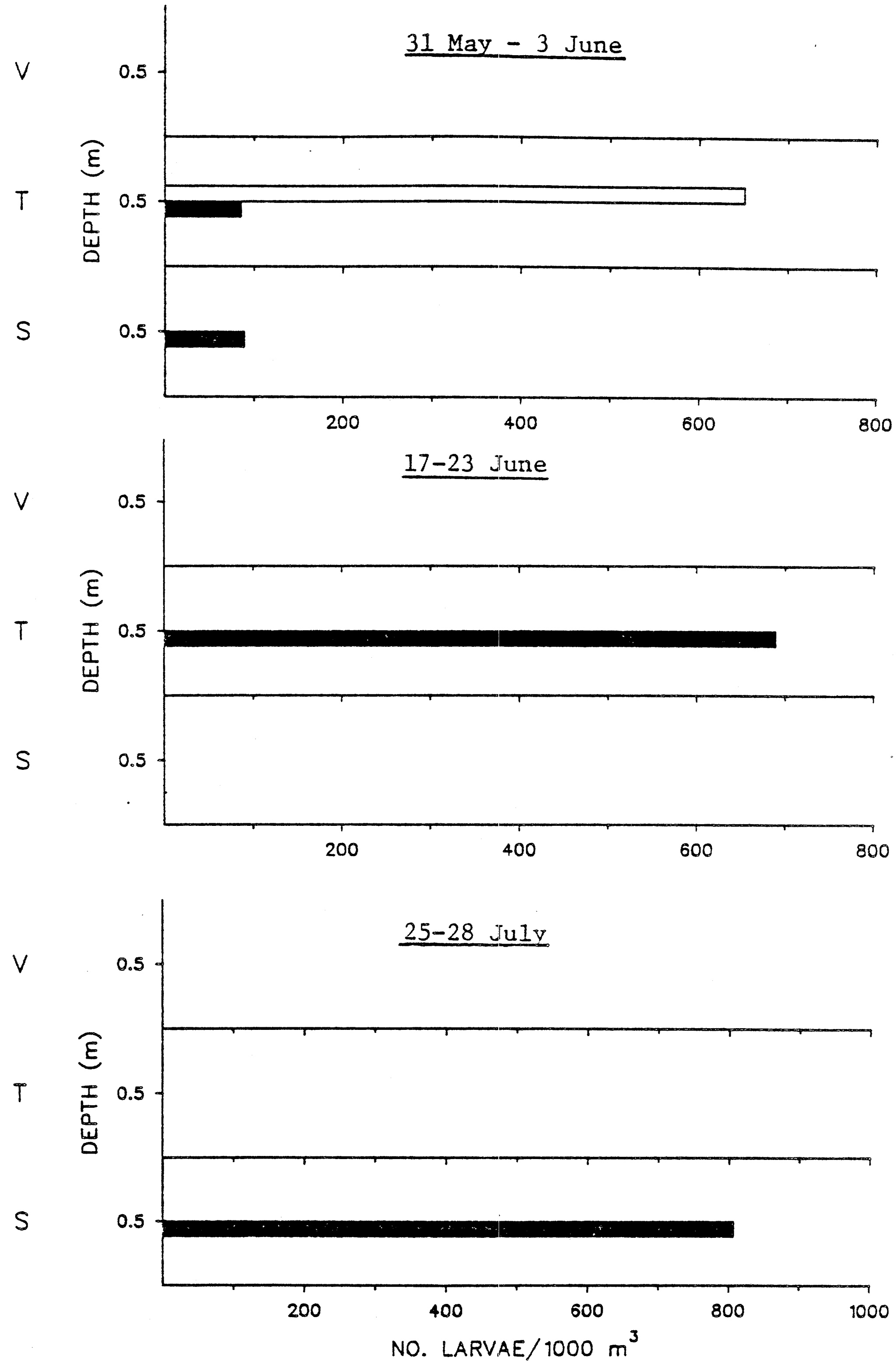


FIG. 105. Number of golden shiner larvae per 1000 m³ for beach stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 1977. □ = Day ■ = Night

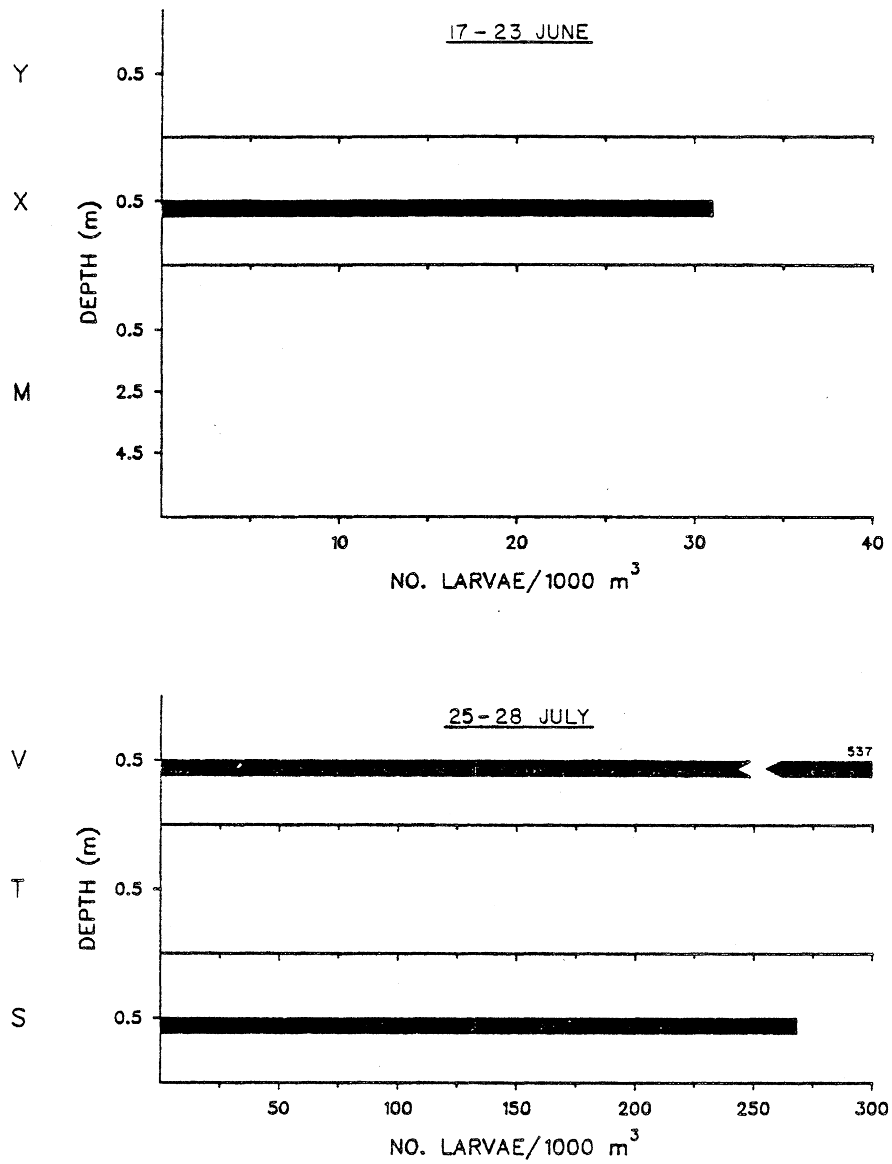


FIG. 106. Number of carp larvae per 1000 m^3 for beach and openwater stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 1977. □ = Day ■ = Night

long); a 4 m night sample at 18 m station G (6.8 mm); a 4 m sample at 6 m station L (6.0 mm) (Fig. 109). One larva (10.5 mm) was also taken during the day on 28 July at station I (1.5 m - n.) (Fig. 110). One carp larva (7.3 mm) was also captured during the night on 21 July in a bottom sled tow at beach station Q (s. discharge) (Appendix 9).

During the apparent peak abundance of carp larvae in July, 13

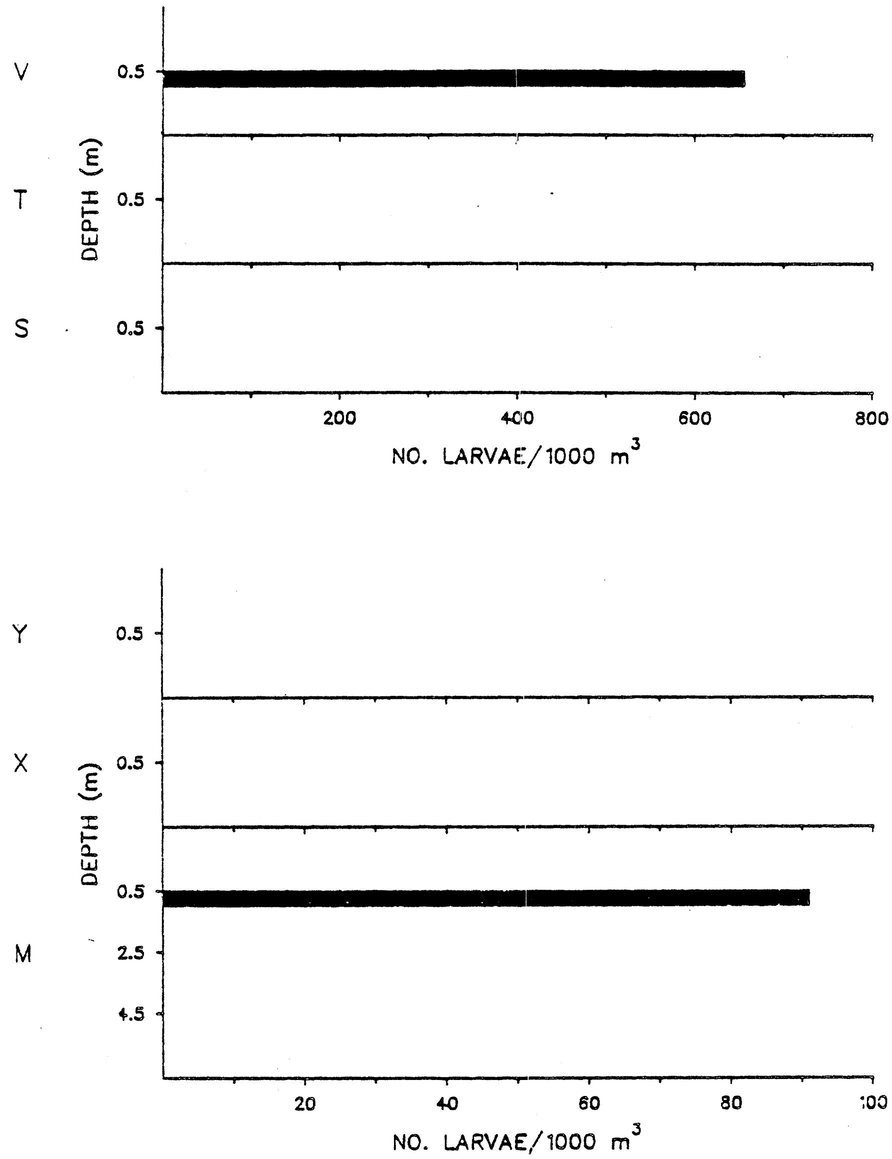


FIG. 107. Number of carp larvae per 1000 m^3 for beach and openwater stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 7-10 July 1977. ☐ = Day ■ = Night

larvae were also removed from entrainment samples. These larvae were all small, from 5 to 6.5 mm (newly hatched), and were all captured at night. Water temperatures in the intake were 21.7-23.4 C. These larvae

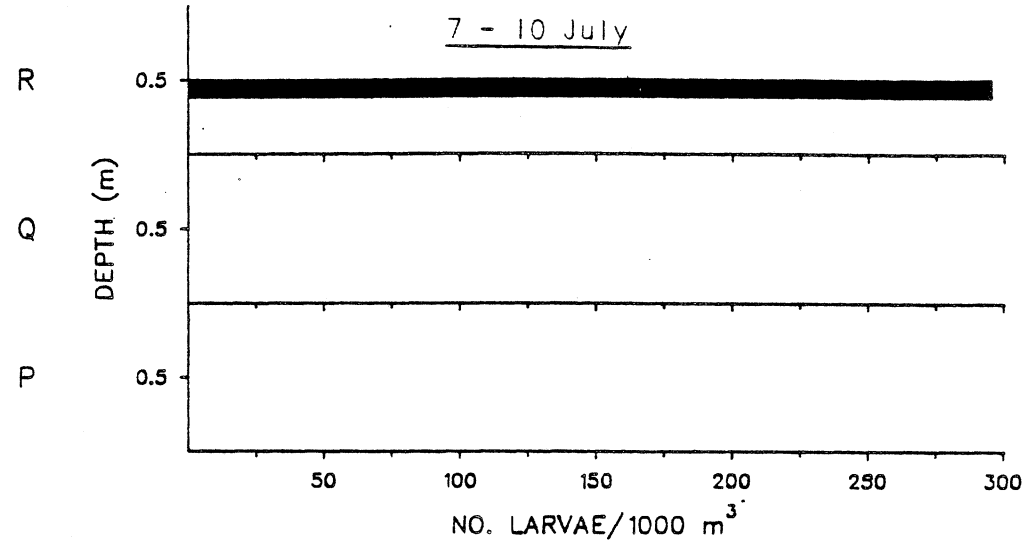


FIG. 108. Number of carp larvae per 1000 m^3 for Lake Michigan beach stations near the J. H. Campbell Plant, eastern Lake Michigan, 1977. □ = Day ■ = Night

resulted in entrainment concentrations of 35/1000 m^3 on 8 July and an average density of 27/1000 m^3 on 21 July. Carp larvae were present in both Pigeon Lake and Lake Michigan at this time, with this size range of carp present in both habitats. Origin of entrained carp is unknown. Presence of these larvae in entrainment samples may have resulted from carp spawning in the intake canal. We observed many large adult carp in the intake canal during June and July of both 1977 and 1978.

Carp taken in field collections ranged from 4.5 to 23.5 mm with most in the 4.5-9 mm range. These fish were caught at water temperatures ranging from 11.8 to 28.0 C. Of the 47 carp larvae entrained and collected in the field only three were captured during the day, the remaining 44 were all caught at night. Predominance of night-caught larvae indicates either daytime net avoidance or demersal behavior. However only one larva out of 11 taken in Lake Michigan was observed in a sled tow, suggesting a pelagic existence for recently hatched carp larvae. We thus suspect that carp larvae actively avoided nets towed during the day. In Pigeon Lake, carp were never collected at the Pigeon River influenced stations T or X; whereas many were taken at other beach and openwater stations in Pigeon Lake. The only reason that can be advanced for the absence of carp larvae at station T is net avoidance. Carp probably spawned early in this area of Pigeon Lake,

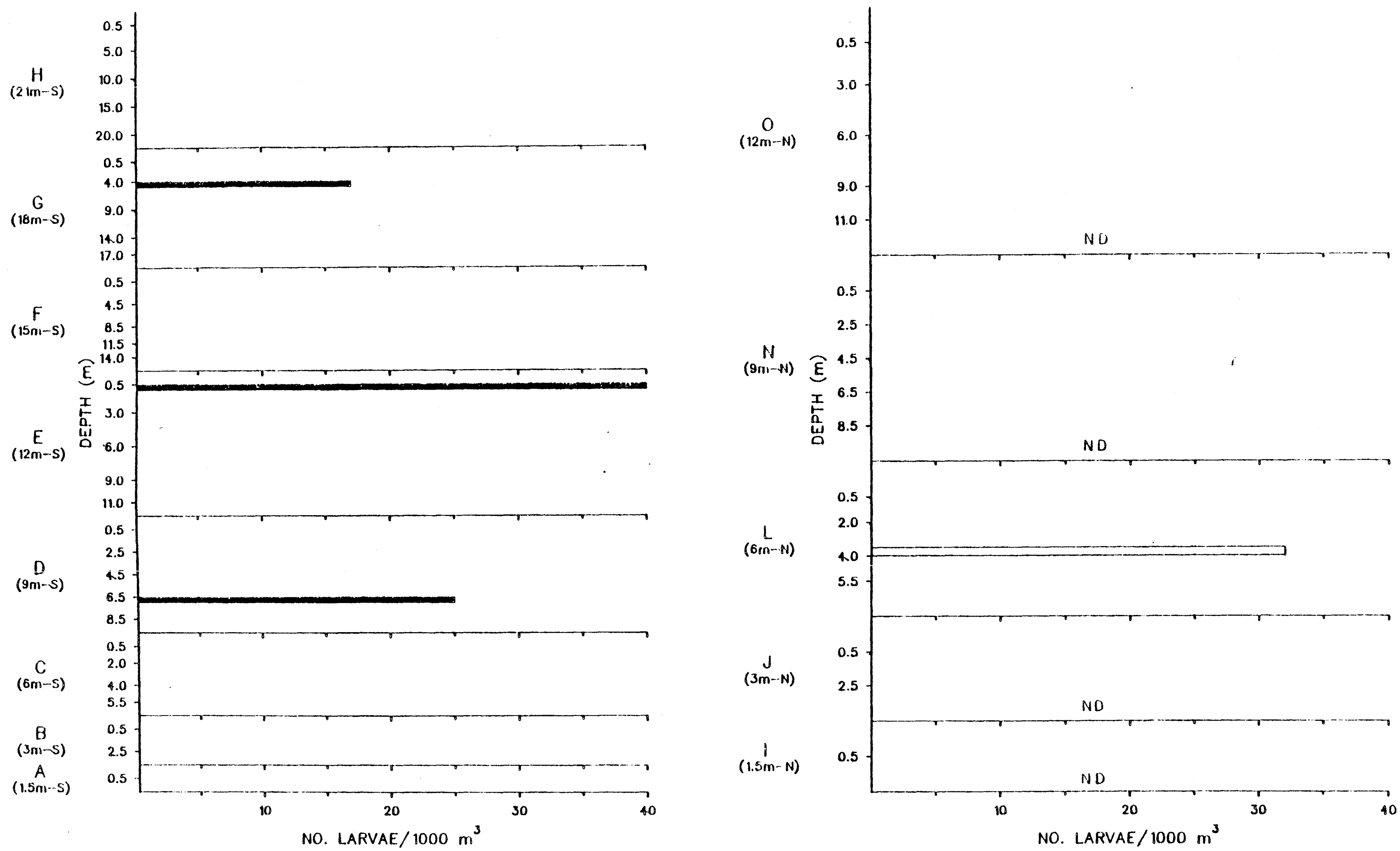


FIG. 109. Number of carp larvae per 1000 m^3 for openwater Lake Michigan stations near the J. H. Campbell Plant, eastern Lake Michigan, 7-10 July 1977. □ = Day ■ = Night
ND = no data

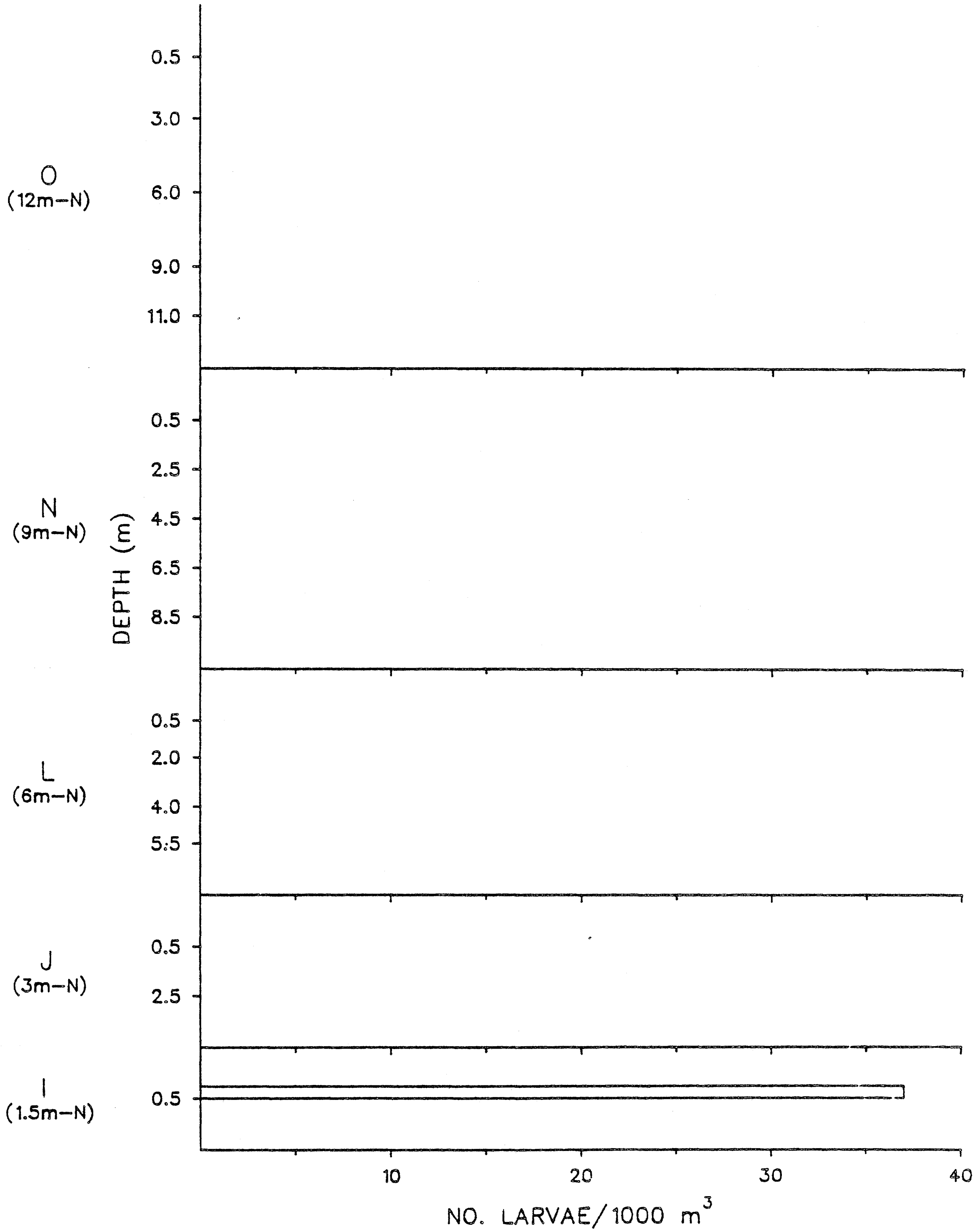


FIG. 110. Number of carp larvae per 1000 m^3 for north transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 25-28 July 1977. □ = Day ■ = Night

allowing carp larvae there to grow to a size which was not vulnerable to our larvae sampling gear. Support for this hypothesis was a 30 mm YOY carp captured at night during July in a seine haul at station T (Appendix 4).

Carp spawning begins in spring and early summer when water temperatures reach at least 17 C and may continue for several weeks. Swee and McCrimmon (1966) believe spawning may extend from May to August in the Great Lakes. Carp move into vegetated shallow water to spawn. Eggs become attached to submerged vegetation and hatch within 3-6 days (Scott and Crossman 1973). Fish (1932) reported that early larvae of carp were large (9-10 mm long); newly hatched larvae measured 5.0-5.5 mm (McCrimmon 1968). The relatively small size of larvae collected from June through July at Campbell suggested that spawning was occurring throughout this time.

Jude et al. (1975) found that carp did not spawn during 1973 in the vicinity of the Cook Plant but data collected in later years showed that spawning around the discharge occurred regularly, especially in July. Few ripe carp were taken in Lake Michigan, near the Campbell Plant or from Pigeon Lake. Pigeon Lake, however, has areas of dense vegetation which would provide suitable spawning habitat for carp. McCrimmon (1968) found that by the time carp larvae reached 8.0 mm, they were free-swimming and moved about the area. It is likely that larvae found in Lake Michigan samples were hatched in the area around the thermal discharge or in the discharge canal since conditions there, warm flowing water and abundant habitat, are ideal for spawning. In fact in early July 1978 we observed carp spawning throughout the discharge canal. The small number of carp larvae collected from Pigeon Lake as well as the small number of ripe adults captured during 1977 suggests that only limited spawning may have occurred there.

Emerald Shiner Fry--

Two emerald shiner fry (32.5 and 35.0 mm) were collected on 7 July in a night fish larvae surface tow at Pigeon Lake beach station S (influenced by Lake Michigan). One fry (32.5 mm) was also entrained on 28 November.

Emerald shiners reportedly spawn from June through August in Lake Erie (Flittner 1964) and in Lewis and Clark Lake, South Dakota (Fuchs 1967). Spawning takes place inshore over clean sand, hard mud bottoms and over shoal areas (Flittner 1964).

Fry collected in Pigeon Lake during July were probably spawned at the very beginning of the 1977 spawning season to have achieved 32-35 mm by the first week of July. The fry entrained in November was a YOY probably hatched later in the spring. Appearance of emerald shiner fry

at station S also raises the possibility that some unknown cyprinids collected here and at other stations, could have been emerald shiners. However since only four adults were collected (three in Pigeon Lake, one in Lake Michigan) and low numbers of fry were observed (three), abundance of larval emerald shiners must be low.

Unknown Cyprinidae --

Minnows which could not be identified with certainty to the genus or species level were tentatively categorized as unknown cyprinids. As a result, larvae in this taxonomic category in many cases were the most numerous larvae noted at a station and along with alewife comprised the majority of larvae entrained at the Campbell Plant.

In Pigeon Lake, unknown cyprinids were abundant (3155 larvae/1000 m^3) during the 31 May-3 June sampling period in night tows at beach station T (influenced by Pigeon River) (Fig. 111 and Appendix 8). Fewer (93/1000 m^3) were caught during the day at this station, which marked the only time unknown cyprinid larvae were captured during daytime at any station during the early June period. These cyprinids were also abundant at beach station S (influenced by Lake Michigan) (1611 larvae/1000 m^3) at night. Lesser numbers were observed exclusively at night at beach station V, openwater stations X, M and Y and in the intake canal at station Z (Fig. 111). Larvae were caught during the day only at the most turbid station (T) where net avoidance would be minimal. Specimens at all other stations were caught at night. This pattern indicated that these larvae were either demersal (unlikely since some were caught during the day in surface tows) or that they actively avoided plankton nets.

Since adult bluntnose minnows were thought to have spawned in late May and bluntnose larvae were identified from some stations, most unknown cyprinid larvae were thought to be bluntnose minnows. More support for this contention was that spottails, the only other abundant larvae, were easy to separate from bluntnose minnows.

Pigeon Lake results for unknown cyprinids during the 17-23 June sampling period (Fig. 112) were similar to those observed in the early Jude period. Again, larvae were taken during the day in low numbers (13-90/1000 m^3) at beach station T and station Z (intake canal). Largest concentrations were observed at night at station T (919/1000 m^3), but some larvae (up to 340/1000 m^3) were collected at beach stations V and S and openwater stations X and M.

The only occurrence of unknown cyprinids in Lake Michigan during June was at the 3 m station B, south transect (Fig. 113) and beach station R near the present discharge (Fig. 114). Concentration of larvae at these stations ranged from 0-146/1000 m^3 at night, none were

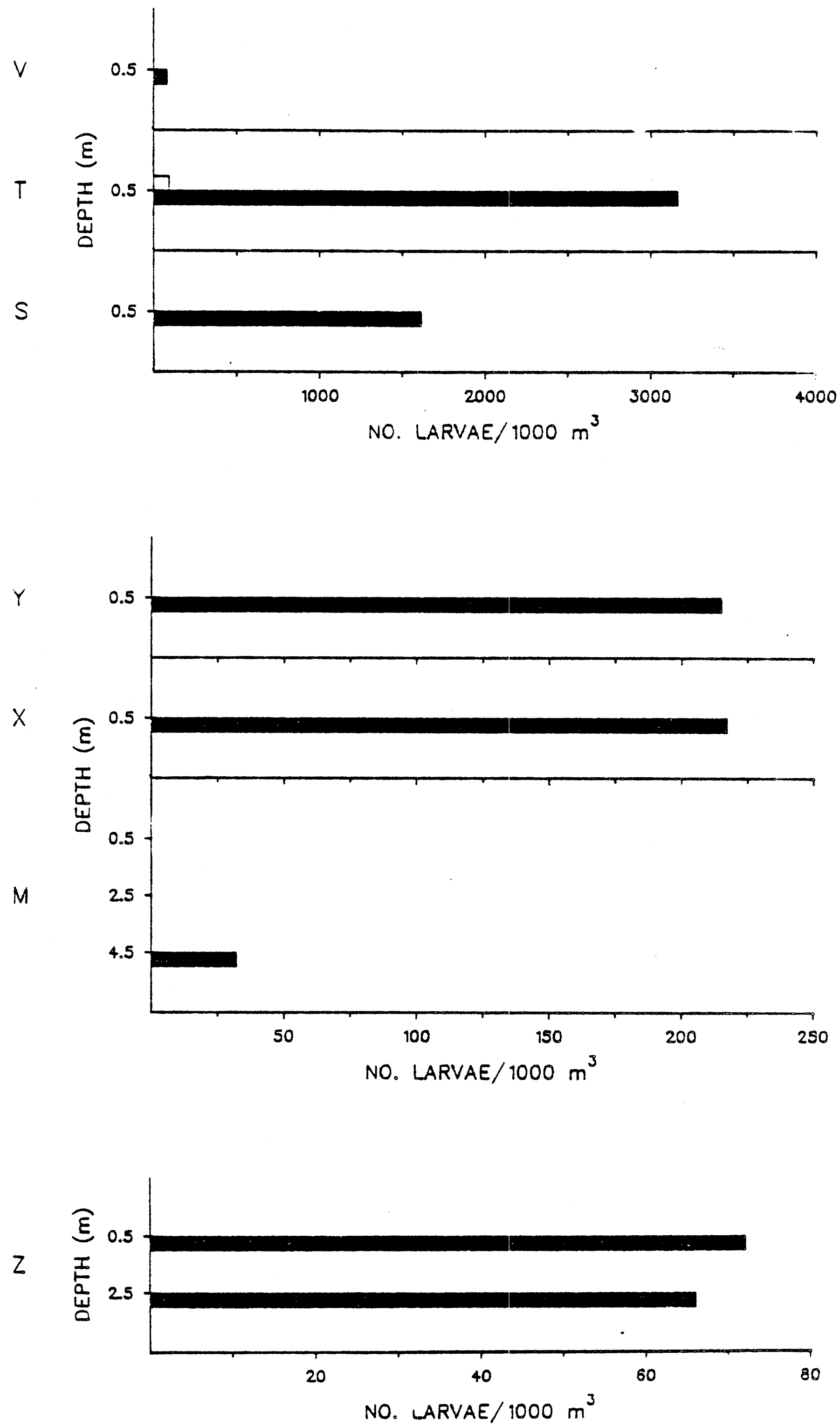


FIG. 111. Number of unidentified cyprinid larvae per 1000 m^3 for beach, openwater and intake canal stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 31 May - 3 June 1977. □ = Day ■ = Night

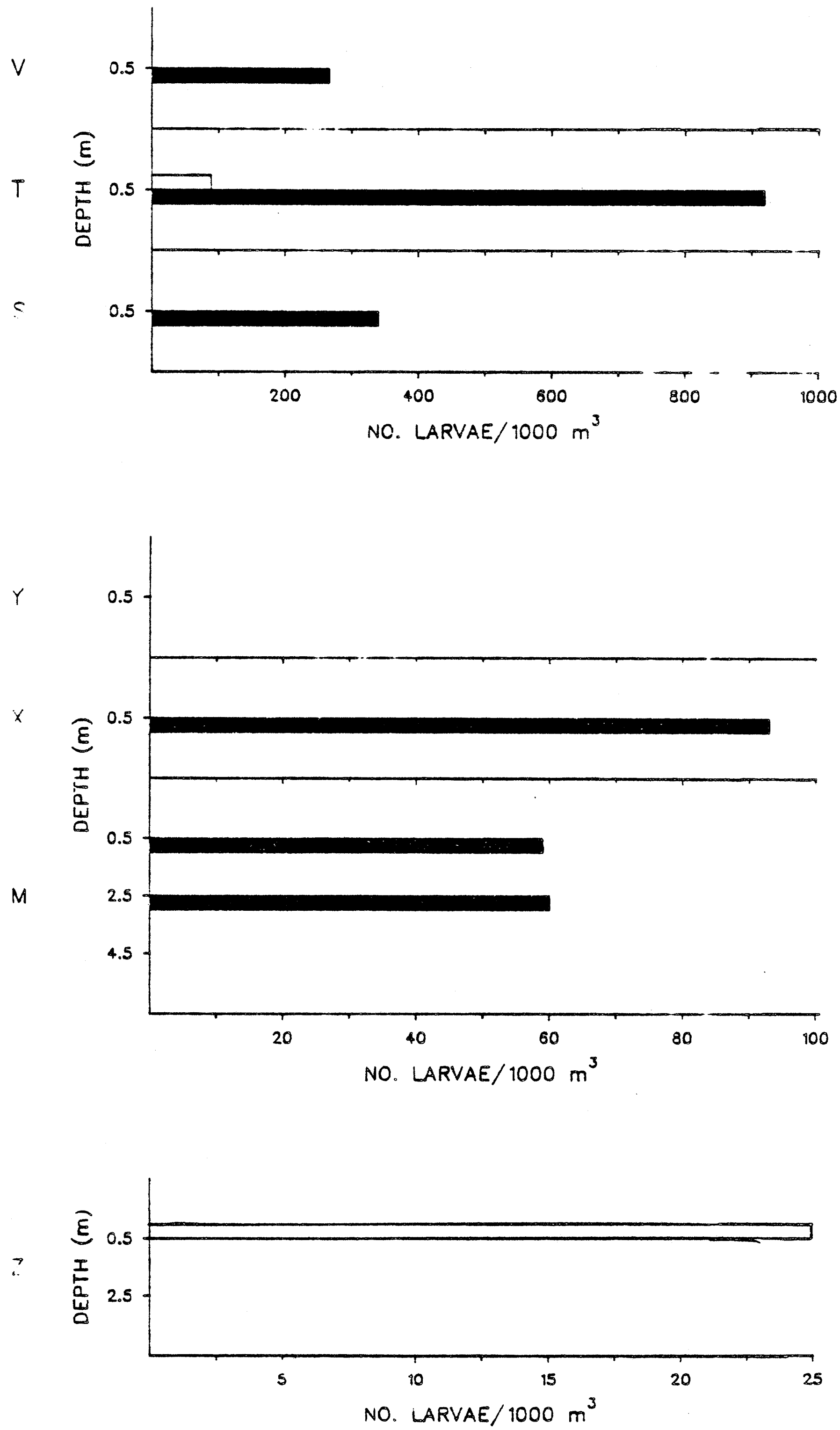


FIG. 112. Number of unidentified cyprinid larvae per 1000 m^3 for beach, openwater and intake canal stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 17-23 June 1977.
□ = Day ■ = Night

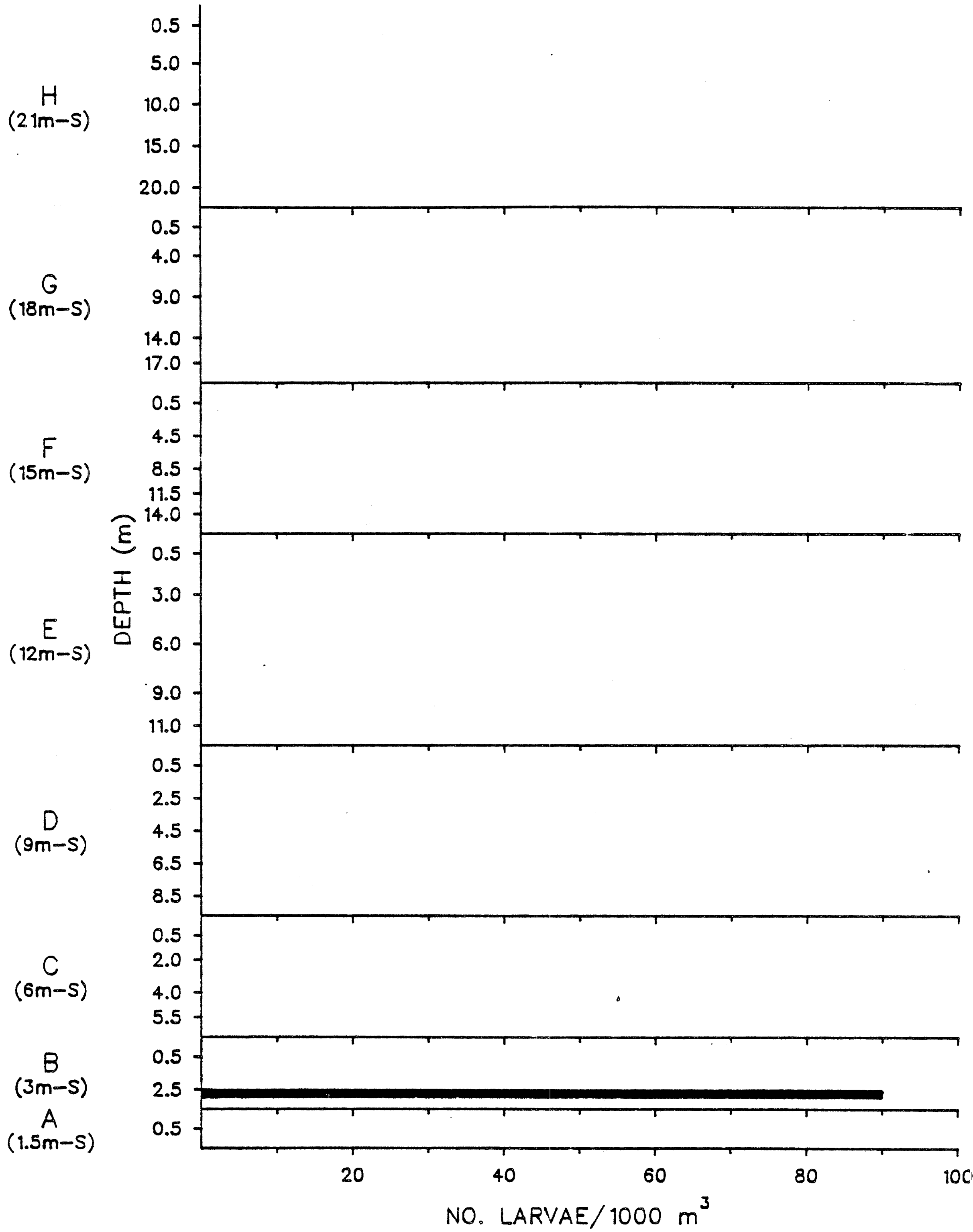


FIG. 113. Number of unidentified cyprinid larvae per 1000 m^3 for south transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 17-23 June 1977. □ = Day ■ = Night

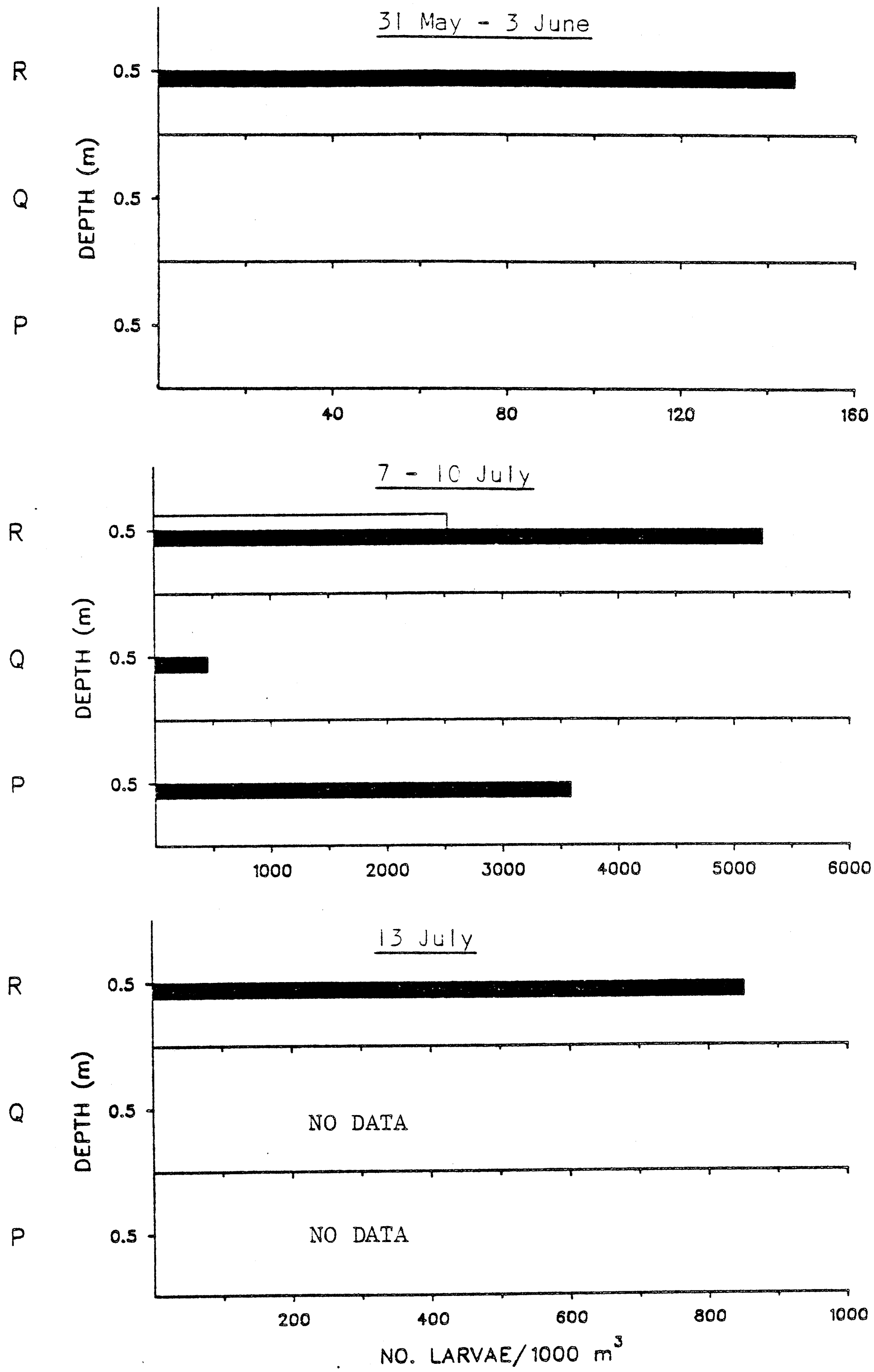


FIG. 114. Number of unidentified cyprinid larvae per 1000 m^3 for Lake Michigan beach stations near the J. H. Campbell Plant, eastern Lake Michigan, 1977. □ = Day ■ = Night

collected in Lake Michigan during the day. These larvae were undoubtedly spottail shiners because (1) spottail adults were the only abundant cyprinid in this area of Lake Michigan, (2) this time (1-23 June) coincided with appearance of spottail larvae at other nearby Lake Michigan areas (Cook Plant), (3) the strongly demersal distribution of spottails in inshore waters (3 m of water or less) (Jude et al. 1975), and (4) spottail larvae were present at some stations during this period.

A large size range of larvae, from about 4 to 17 mm, was present at Pigeon Lake stations during June (Fig. 115). Spawning by adults of these larvae (thought to be bluntnose minnows) apparently was confirmed for mid to late May. Net avoidance was also quite apparent from these data, since larvae caught during the day at all beach stations were small (about 6 mm) while night-caught specimens ranged in length from 4-17 mm (Fig. 115). Larvae caught at night at Pigeon Lake openwater stations were 5-10 mm long; none were caught during the day.

In June Lake Michigan pooled length-frequency samples of unknown cyprinids, thought to be spottail shiners, showed that larvae there were in the 5-6 mm range (Fig. 115). The length range of larvae caught at Pigeon Lake station M (Lake Michigan influenced) and in the intake canal (Z) was also 5-7 mm, raising the possibility of transport of larvae from Lake Michigan, through Pigeon Lake and into the intake canal.

During both July sampling periods (7-10 and 25-28) distribution of unknown cyprinids at Pigeon Lake stations remained essentially the same as in June (Figs. 116, 117). However, numbers at night were much lower at station T while numbers collected at beach station S (Lake Michigan influenced) rose sharply from June levels of 340-1611 to 7058-8775/1000 m^3 in July. During the day in July, small numbers of larvae were collected at stations M, S, T, V, and Y (7 - 182 larvae/1000 m3). The range of sizes of cyprinids was larger for all Pigeon Lake samples pooled than the range observed at stations M (6 m) and Z (intake canal) where only smaller larvae were collected (Fig. 118). The wider range of larvae being available at Pigeon Lake stations not influenced by Lake Michigan may be related to: (1) earlier spawning in Pigeon Lake, and therefore availability of larger cyprinid larvae, and (2) greater catchability of larvae because of the more turbid waters at beach stations compared with openwater station M and the intake canal, station Z. It may also be that only the smaller larvae are found in openwater, being transported more widely by currents due to their inability to resist them.

Of the three sampling surveys conducted in Lake Michigan, two included all stations on 7-10 and 25-28 July, while one survey trip included only north transect stations with samples collected at surface, mid-depth and bottom. These data were collected by Consumers Power

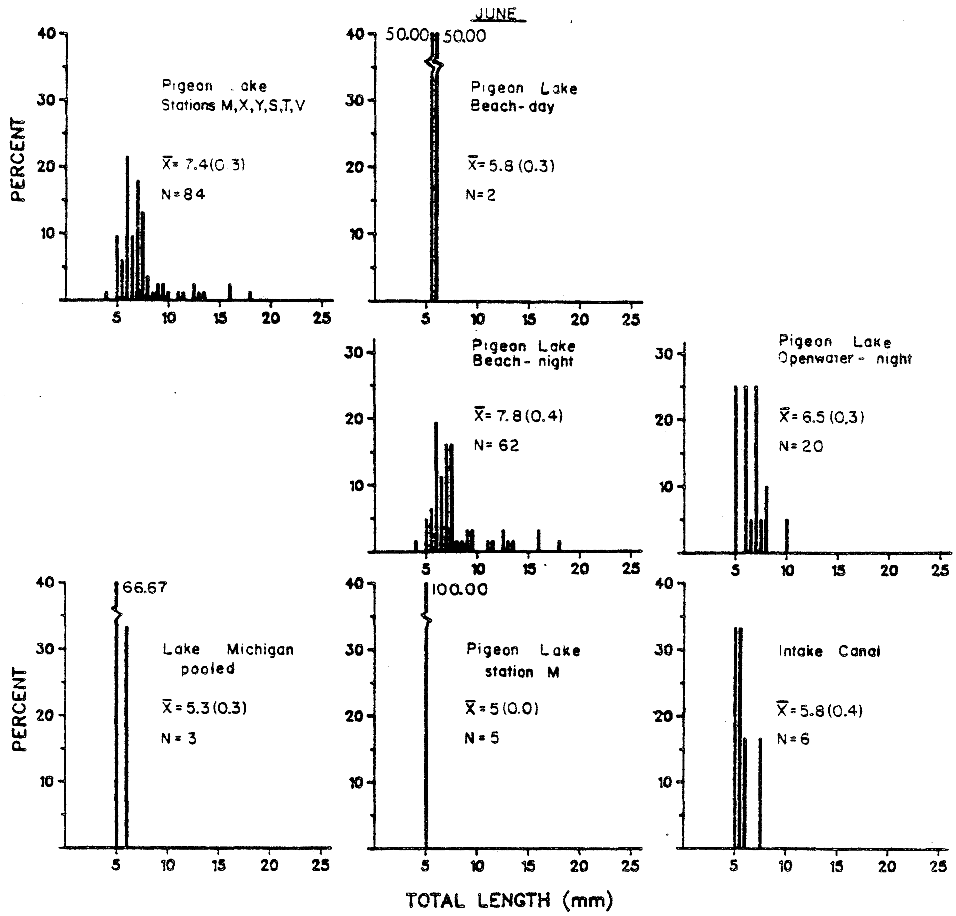


FIG. 115. Length-frequency histogram for unidentified cyprinid larvae caught at selected pooled stations in Lake Michigan and Pigeon Lake near the J. H. Campbell Plant, 1977. All tows were net tows unless sled tows were specified. ($\overline{X}$=mean, N=total number of larvae used in the comparison, standard error is given in parenthesis.)

Company personnel on 13 July. Data from the first survey on 7-10 July (Fig. 119) showed high numbers, 3525/1000 m^3, of unknown cyprinids (undoubtedly spottails) at night at the 1.5 m, south transect station A and 3582-5245/1000 m^3 at beach stations R (n. discharge) and P (s. reference) (Fig. 114). None were caught at 1.5 or 3 m stations at the north transect. A few larvae were also observed at south transect stations G (18 m), E (12 m), D (9 m), C (6 m) and B (3 m). At the north transect during early July the only occurrence of unknown cyprinids at openwater stations was in a day sample collected at station L (6 m) at the 5.5 m depth--few larvae, 18/1000 m^3, were found.

Samples collected on 13 July at the north transect only (Fig. 120)

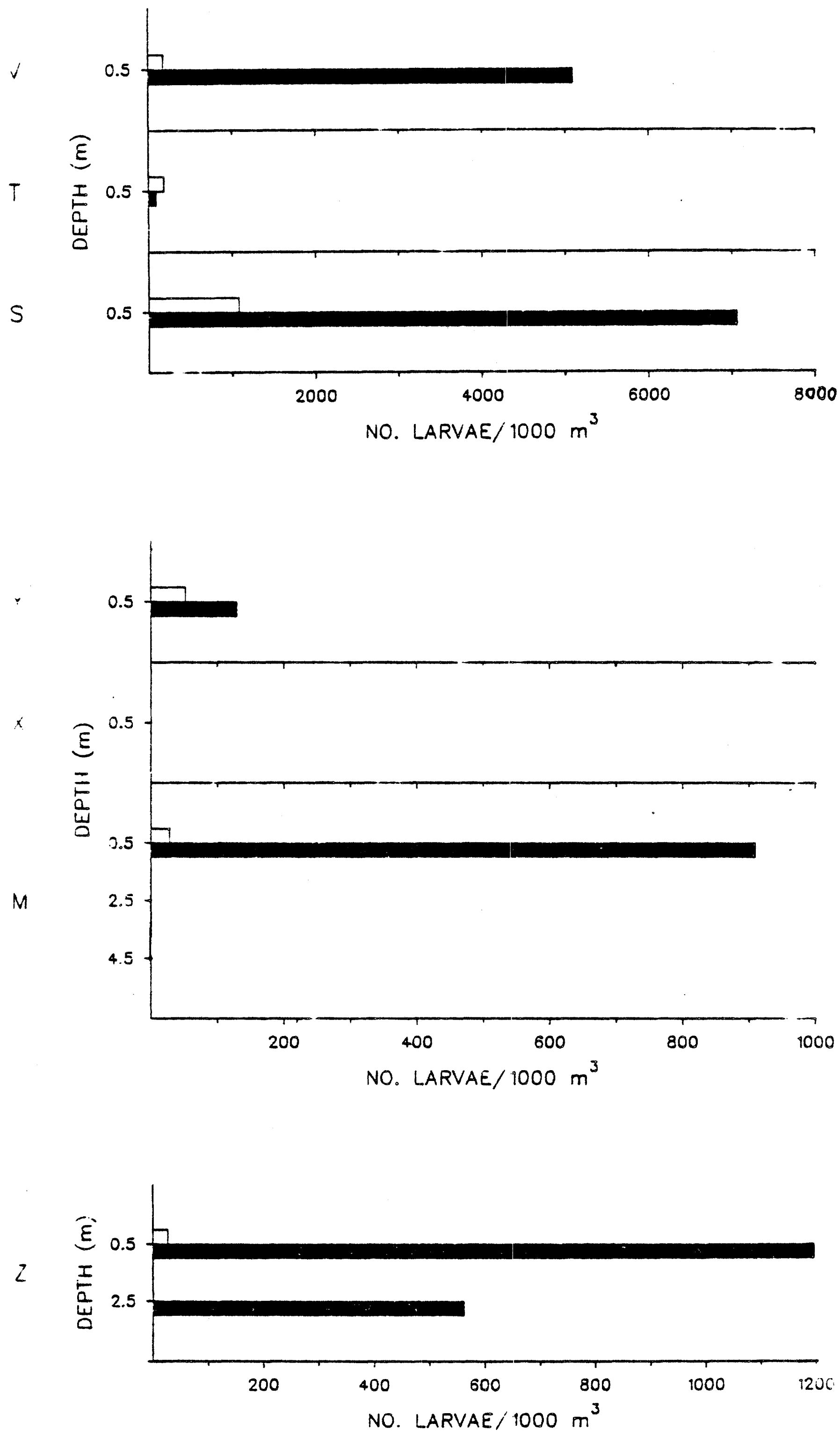


FIG. 116. Number of unidentified cyprinid larvae per 1000 m^3 for beach, openwater and intake canal stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 7-10 July 1977. □ = Day ■ = Night

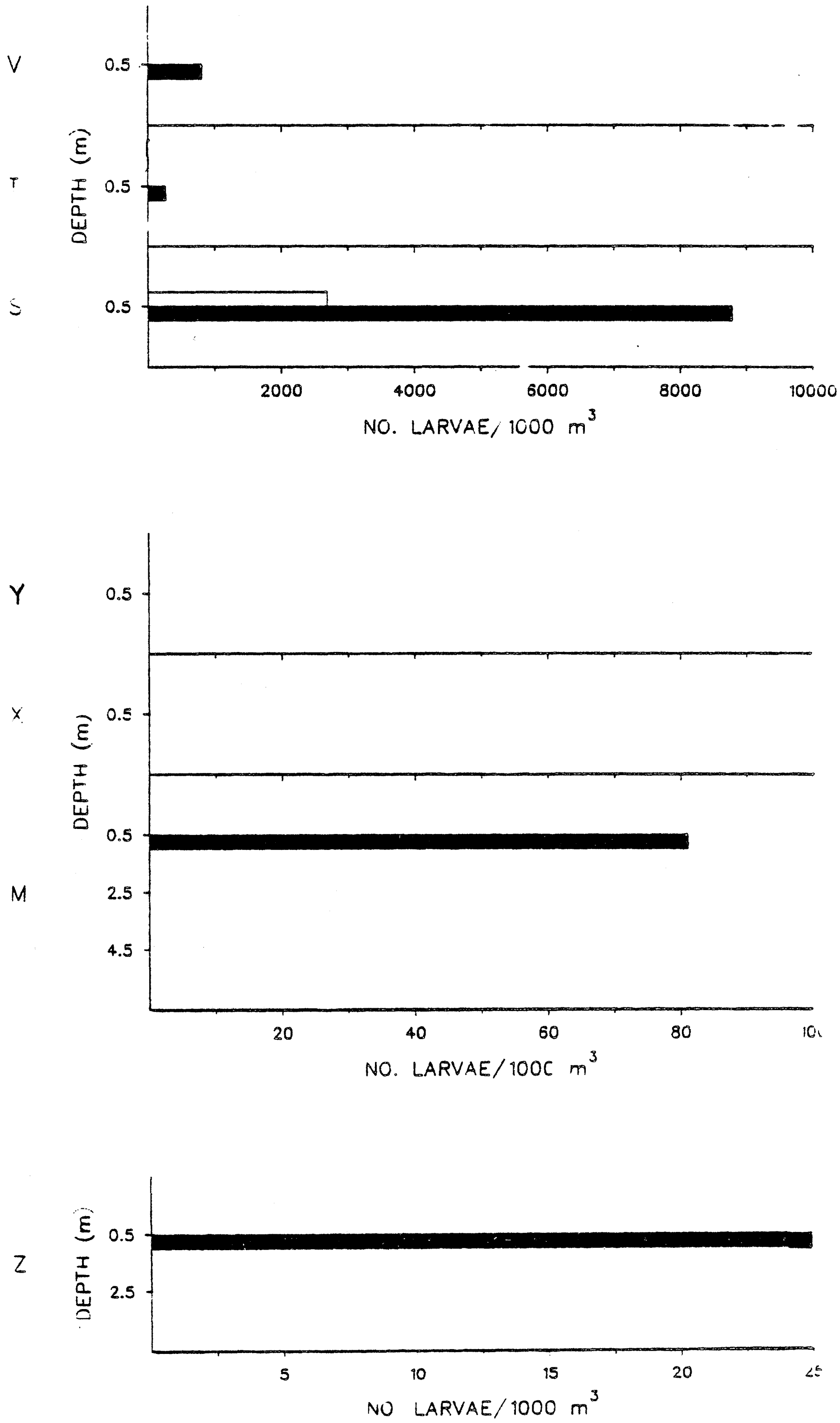


FIG. 117. Number of unidentified cyprinid larvae per 1000 m^3 for beach, openwater and intake canal stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 25-28 July 1977.
□ = Day ■ = Night

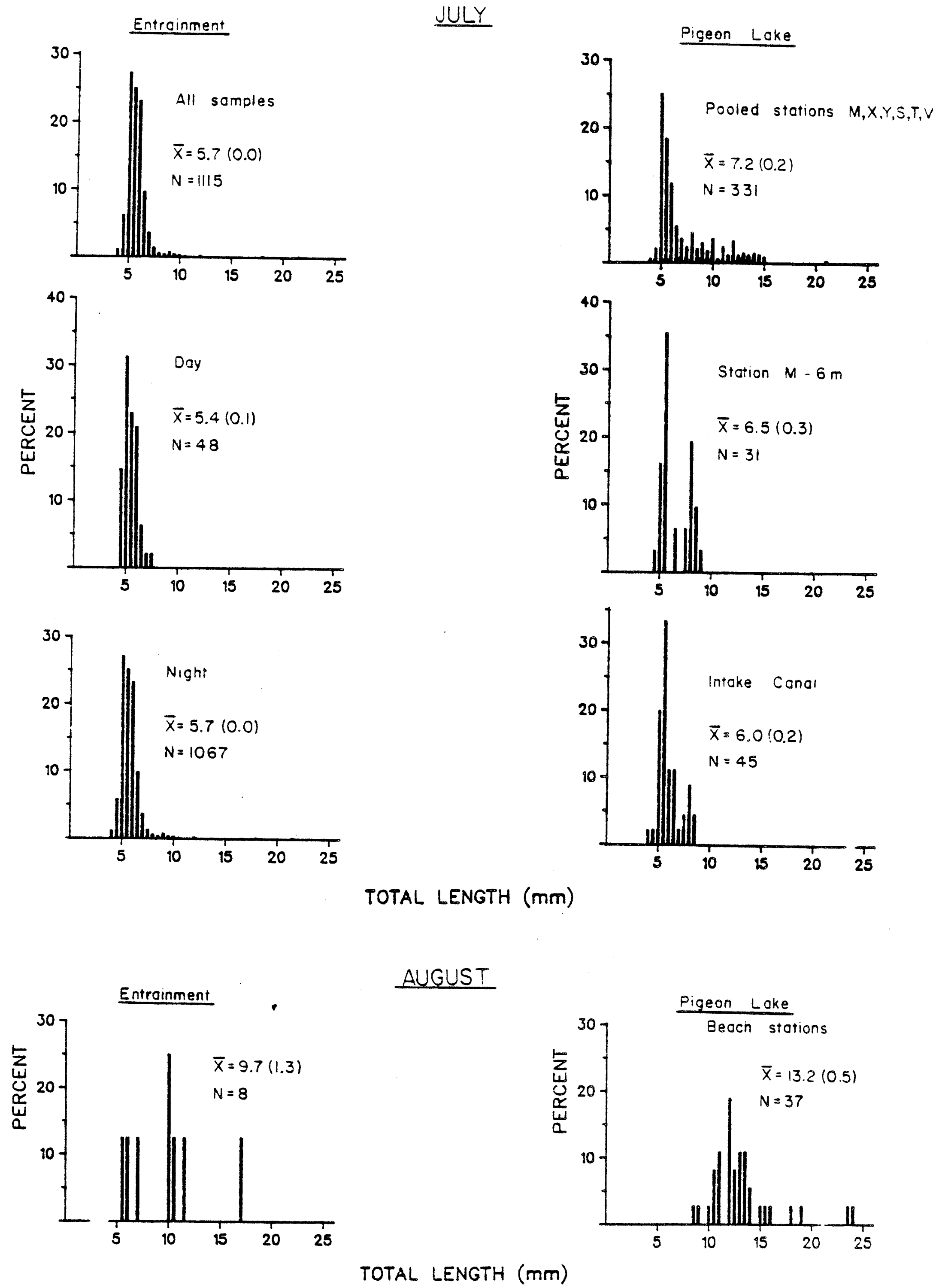


FIG. 118. Length-frequency histogram for unidentified cyprinid larvae caught at selected pooled stations in Lake Michigan and Pigeon Lake near the J.H. Campbell Plant, 1977. All tows were net tows unless sled tows were specified. ($\bar{X}$=mean, N=total number of larvae used in the comparison, standard error is given in parenthesis.)

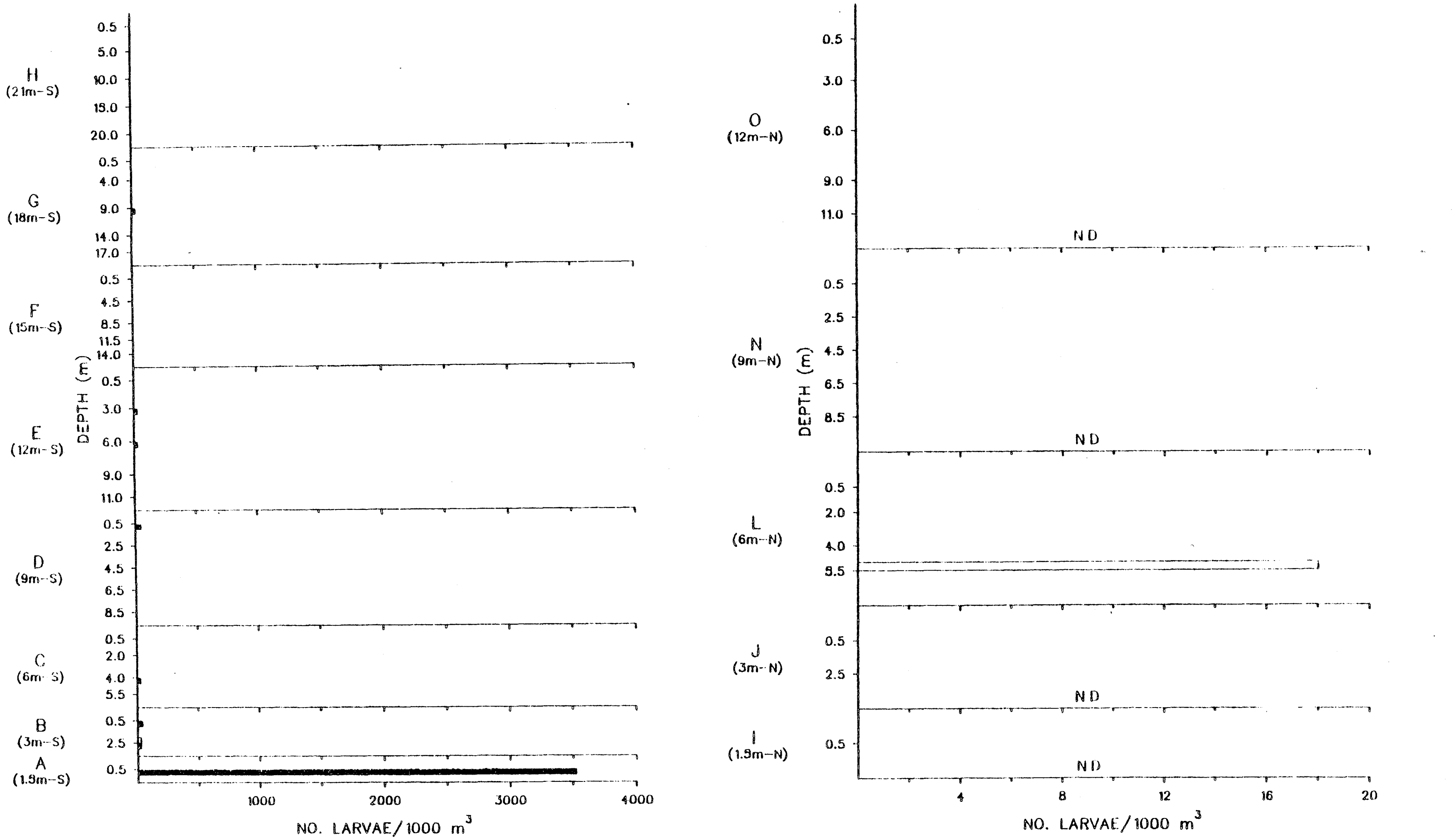


FIG. 119. Number of unidentified cyprinid larvae per 1000 m^3 for openwater Lake Michigan stations near the J. H. Campbell Plant, eastern Lake Michigan, 7-10 July 1977. □ = Day ■ = Night ND = no data

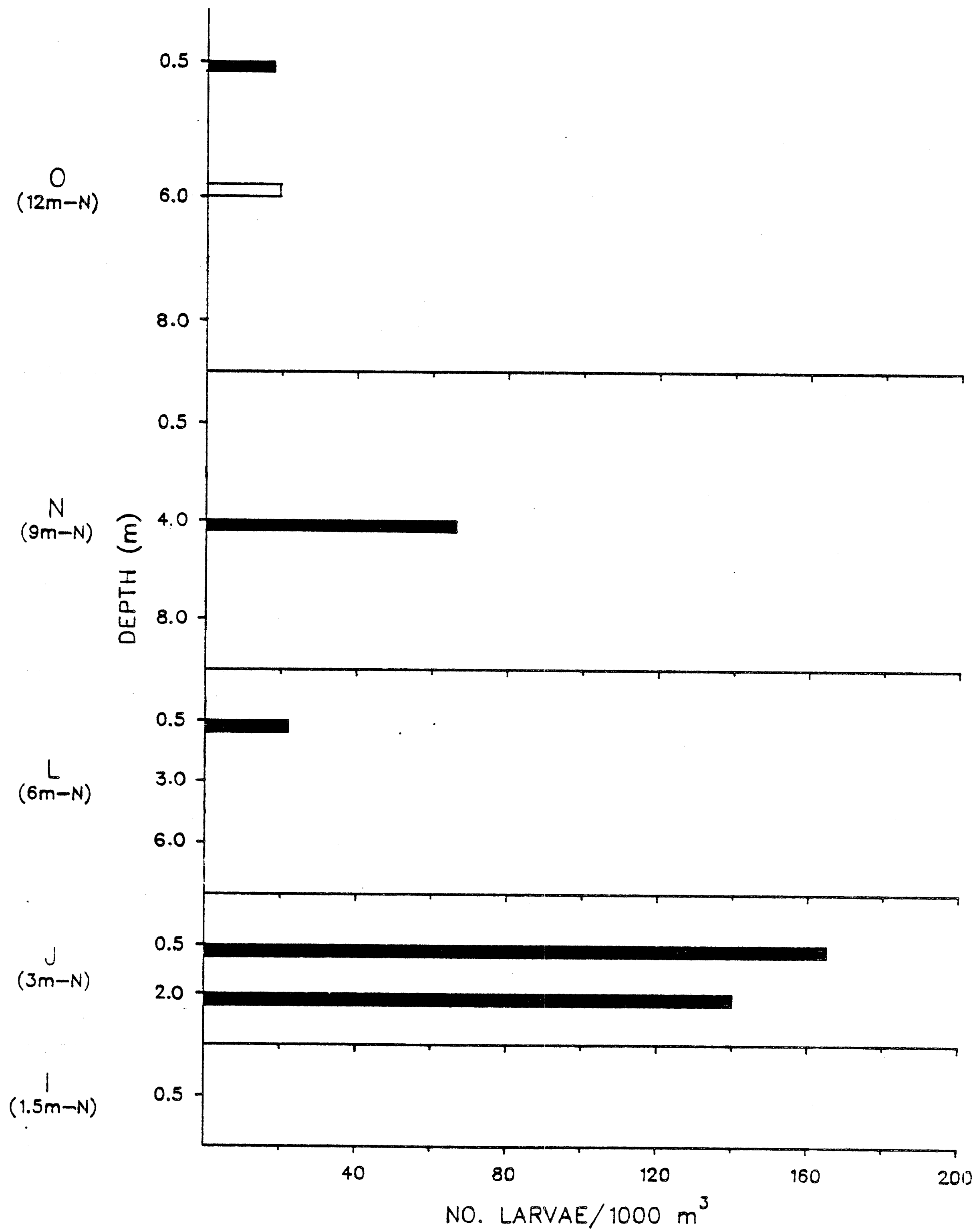


FIG. 120. Number of unidentified cyprinid larvae per 1000 m^3 for north transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 13 July 1977. □ = Day ■ = Night

contained cyprinid larvae in six tows, all except one were collected at night. Larvae were found at 12 m station O (9 m tow), 9 m station N (4 m tow), 6 m station L (surface tow), 3 m station J in both the surface and 2.5 m tow and at beach station R (n. discharge) (Appendix 7). No pattern in distribution was discernible.

During the 25-28 July sampling period in Lake Michigan at north and south transect stations (Fig. 121) few unknown cyprinids were present except at beach stations where $4217/1000\ m^3$ were recorded at station Q (Fig. 122). Larvae were collected at two south transect stations (C - 6 m and B - 3 m) in concentrations of 47 and 822 larvae/1000 m^3 respectively, and one north transect station, N - 9 m, where the concentration was $39/1000\ m^3$. Absence of larvae from offshore stations was probably due to growth of cyprinids to a size where they could be positively identified, and a concomitant increase in net avoidance.

Examination of sled tow data collected during July through October 1977 at most Lake Michigan stations near the Campbell Plant (Appendix 9) demonstrated a definite preference by unknown cyprinids for the bottom at nearshore (3 m or less) stations. Larvae were collected at eight stations and all but one, station C (6 m - s.) were beach, 1.5 or 3 m stations. Concentrations of larvae collected were extraordinarily high, $10{,}566/1000\ m^3$ (Appendix 9), in a night sled tow sample collected on 21 July at 3 m station B (s. reference). The concentration at beach station P (s. reference) was $1886/1000\ m^3$ and at station A (1.5 m - s.) the concentration was $525/1000\ m^3$. Concentrations of unknown cyprinids were similar at north transect beach, 1.5 and 3 m stations, where larvae were present in concentrations ranging from $274\text{-}2889/1000\ m^3$. These data confirmed the predominant inshore distribution of unknown cyprinids. No unknown cyprinids were collected in sled tows after July because most larvae were able to be identified.

Sled tow length-frequency data from July (Fig. 123) also corroborated the pattern of inshore distribution of unknown cyprinids. Data for all sled tows collected showed larvae ranged from about 4-13 mm, with a mode of 5-6 mm. Most larvae (287 out of 289) were collected at beach, 1.5 and 3 m stations; the remaining two larvae were taken at 6 m stations. Of the 287 larvae collected inshore, 269 were taken at 1.5 and 3 m stations. Lengths of larvae captured from these nearshore areas were similar. The two larvae collected at 6 m were fairly large (10-13 mm) compared to beach, 1.5 and 3 m stations, where the most abundant larvae were in the 5-6 mm range.

The modal length interval for unknown cyprinids caught at Lake Michigan beach stations in July (Fig. 123) was 6 mm, undoubtedly newly hatched larvae. However, larvae up to 23 mm were found in July samples, suggesting spawning by adults of this group had occurred possibly in late May or early June 1977. Comparing the length range of larvae

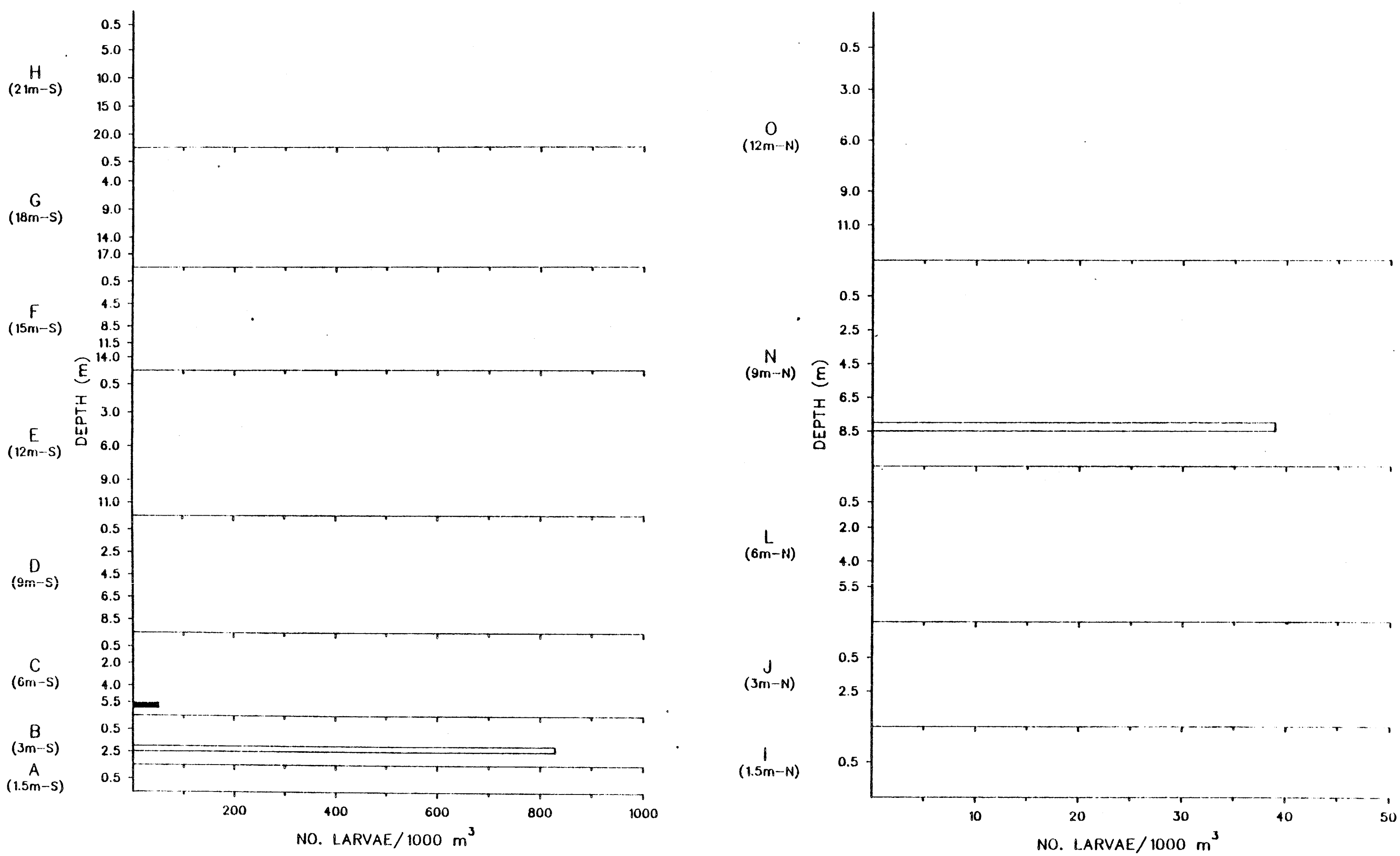


FIG.121 . Number of unidentified cyprinid larvae per 1000 m^3 for openwater Lake Michigan stations near the J. H. Campbell Plant, eastern Lake Michigan, 25-28 July 1977. □ = Day ■ = Night

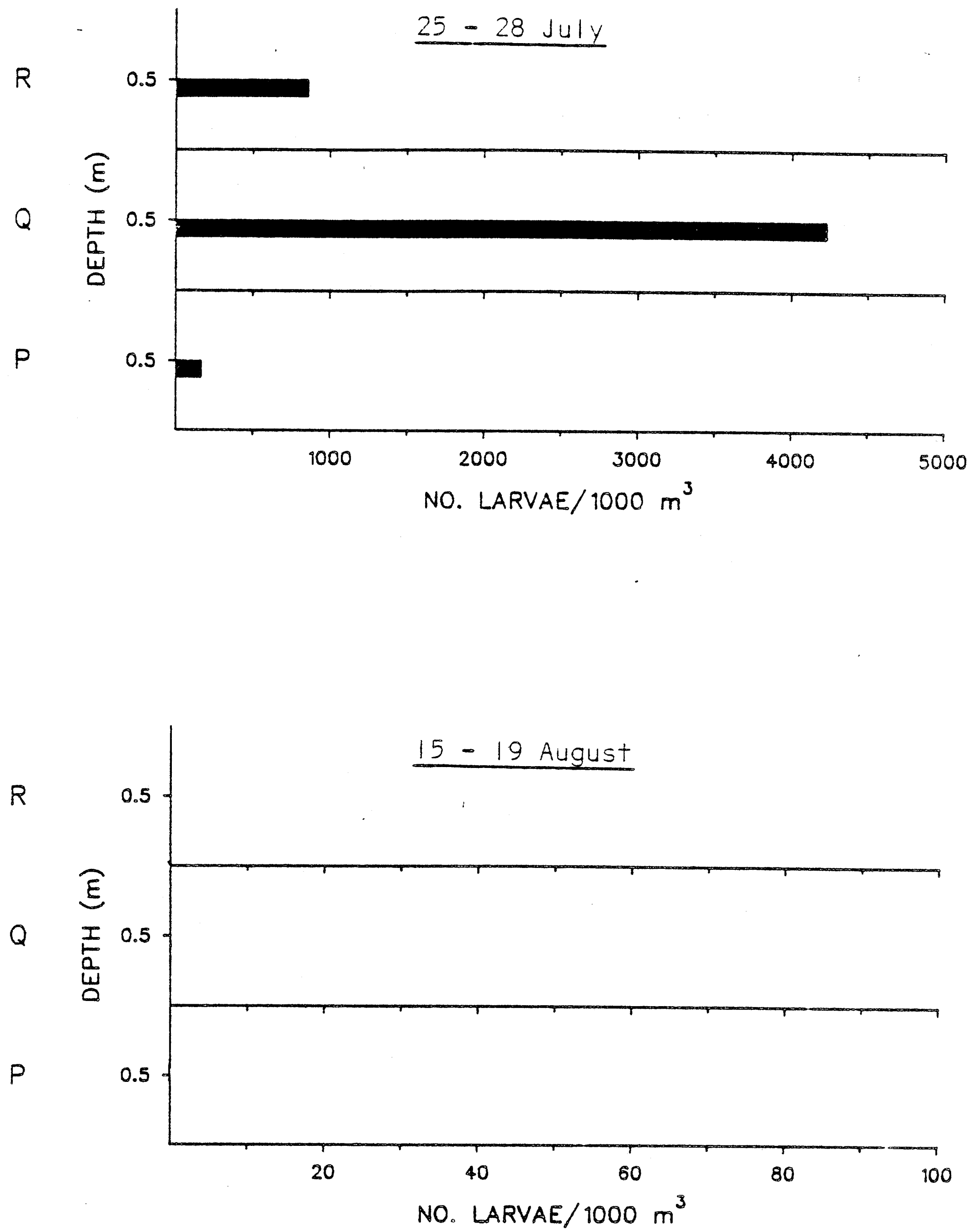


FIG. 122. Number of unidentified cyprinid larvae per 1000 m^3 for Lake Michigan beach stations near the J. H. Campbell Plant, eastern Lake Michigan, 1977. □ = Day ■ = Night

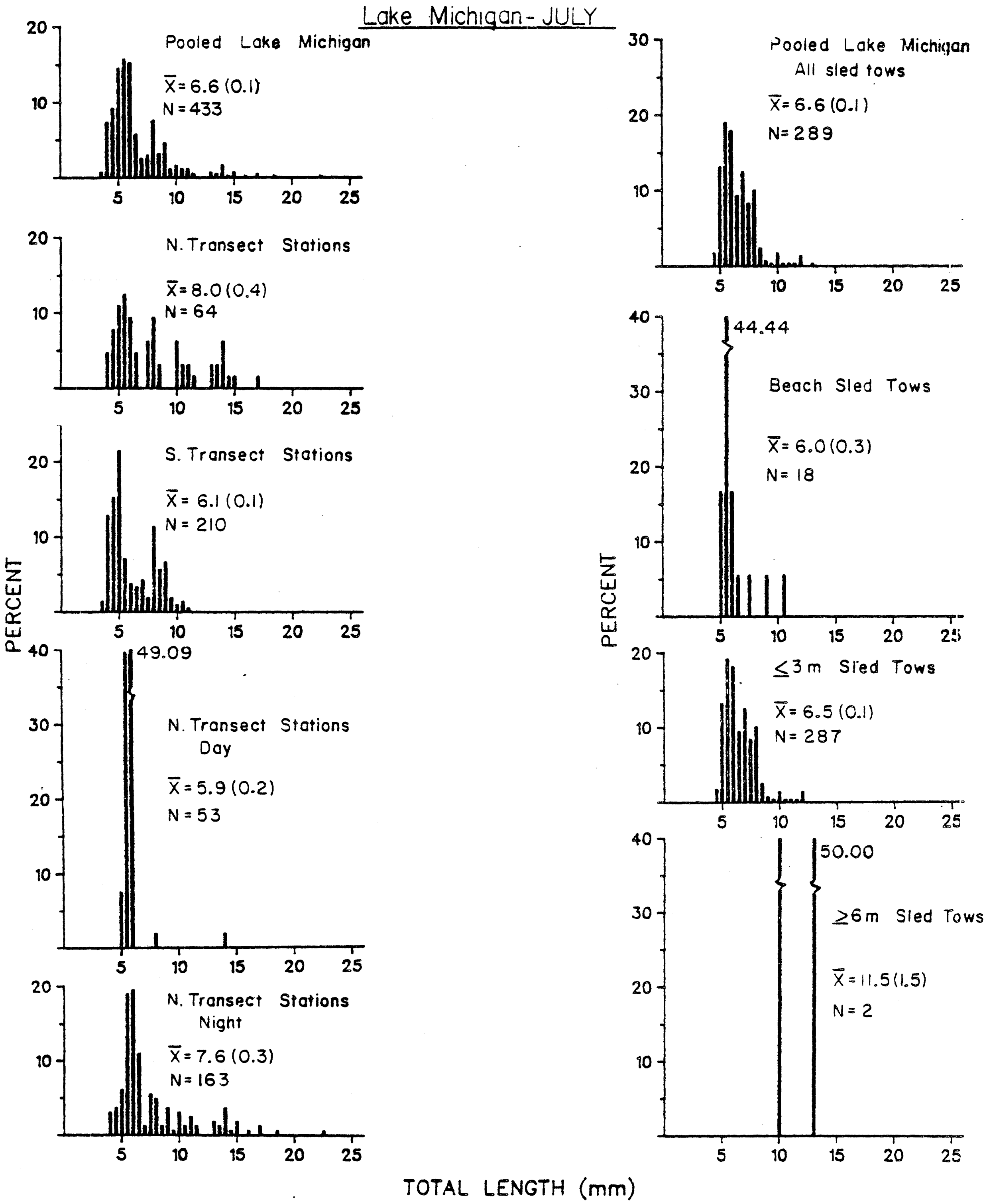


FIG. 123. Length-frequency histogram for unidentified cyprinid larvae caught at selected pooled stations in Lake Michigan and Pigeon Lake near the J.H. Campbell Plant, 1977. All tows were net tows unless sled tows were specified. ($\overline{X}$=mean, N=total number of larvae in the comparison, standard error is given in parenthesis.)

caught at north transect stations (about 4-17 mm) with those caught at the south reference transect (about 4-11 mm) indicated a possible growth difference between transects, with the transect in the vicinity of the present thermal discharge having longer larvae. Given comparable effort, the numbers of larvae and their range of lengths generally decreased during day sampling in Lake Michigan. For example, 53 larvae (5-14 mm long with a mode of 5-6 mm) were caught during the day at the north transect whereas nearly three times as many larvae (163) were taken at night (Fig. 123). These night-caught larvae ranged from 4 to 23 mm.

Entrainment of unknown cyprinids probably was occurring at high rates long before our first sampling date on 8 July 1977. On that day 598,793 unknown cyprinid larvae were entrained during the night period and 166,808 were entrained during the day period, for a total of 765,601 for that 24 hr period (Fig. 124, Appendix 10). We believe most of these larvae were bluntnose minnows, and efforts to identify these larvae will be made in the future.

Unknown cyprinids continued to be entrained in high numbers through most of July as 189,477 per 24 hrs were entrained on 14 July and 301,093 per 24 hr on 21 July. After 21 July, no significant numbers of unknown cyprinids were entrained. They were only entrained in numbers less than 9000 per 24 hr on 3 August, 16 August and 6 October 1977.

The pooled length-frequency histogram for all unknown cyprinids entrained during July indicated the majority were recently hatched larvae 5.7 mm (Fig. 117). The numbers collected (1067) and length range (4-22 mm) of larvae entrained at night were considerably different than the daytime entrainment samples (N = 48, range = 4-8 mm long). Since we feel that there was no net avoidance bias introduced into our entrainment sampling method (immersion of the plankton net into the approximately 1.8 m/s velocity of the discharge canal), higher numbers of larvae caught during the night must be due to increased activity of the unknown cyprinids.

The dramatic increase in concentration of larvae passing through the plant at night was vividly demonstrated on 8 July, when the daytime concentration of unknown cyprinids was 116/1000 m^3, while the comparable night concentration was 1926 larvae/1000 m^3, a 14 fold increase (Fig. 124). A similar pattern, just as dramatic, was documented for the entrainment samples collected on 14 and 21 July. Because of their apparent increased activity, more larvae were brought into the influence of the intake currents. Such activity under normal circumstances probably serves to disperse larvae away from the spawning area. The hypothesized increased nighttime activity may also be related to feeding behavior.

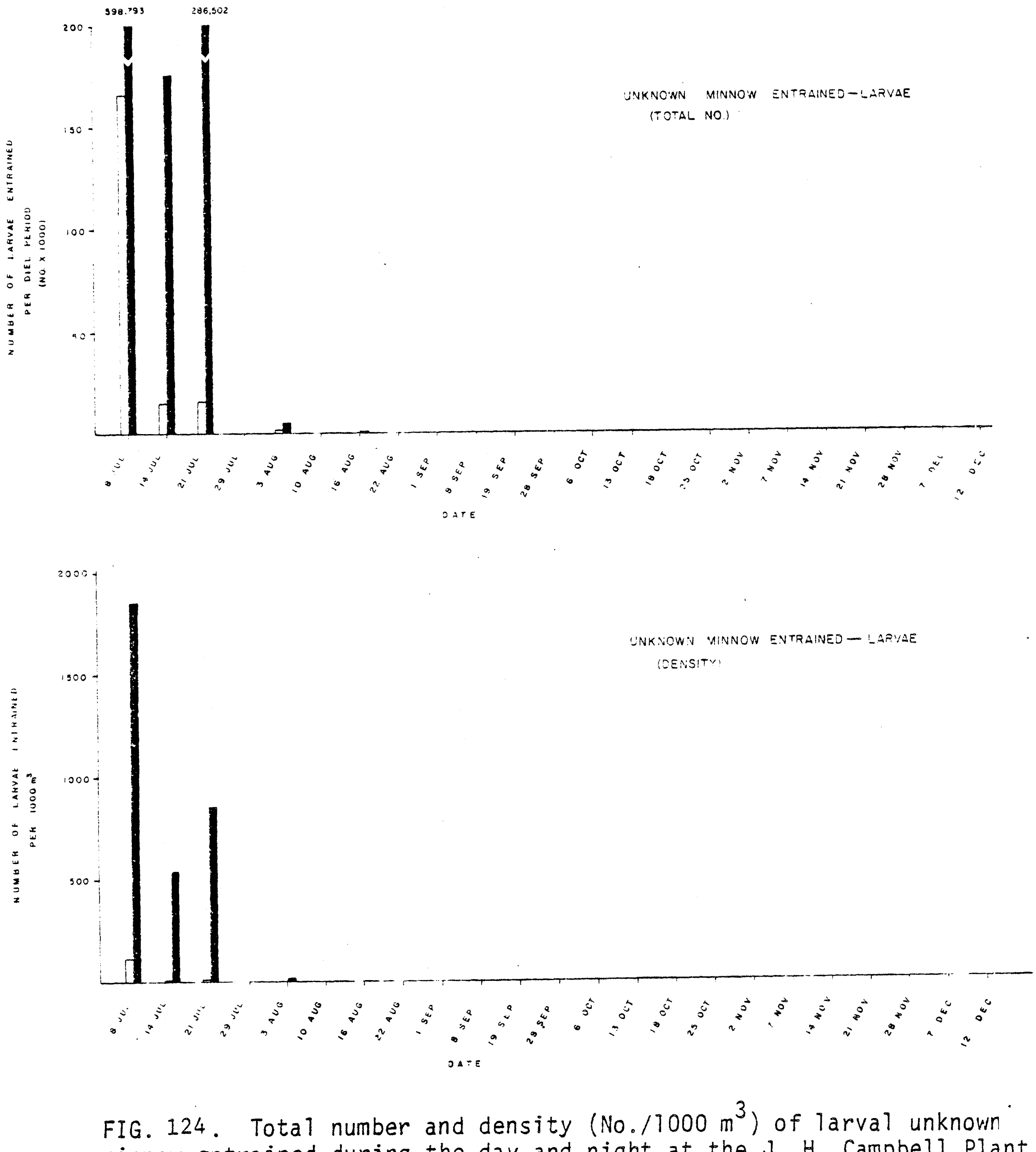


FIG. 124. Total number and density (No./1000 m^3) of larval unknown minnow entrained during the day and night at the J. H. Campbell Plant, 1977. ☐ = Day ■ = Night

During August, most unknown cyprinids became identifiable through growth and subsequent attainment of characters critical for identification. No larvae in this category were collected in Lake Michigan during August, but a large number of unknown cyprinids did occur in Pigeon Lake, probably due to the larger number of cyprinid species present there. Therefore, these larvae were more difficult to identify to species. Most unknown cyprinids captured in August in Pigeon Lake were collected at beach station S (influenced by Lake Michigan); remaining larvae were caught at the other two beach stations, V and T (Fig. 125). No larvae were caught at Pigeon Lake openwater stations, suggesting preferred habitat as the littoral zones of Pigeon Lake. Length range of all larvae caught in Pigeon Lake during August was wide, from about 7 to 23 mm (Fig. 118), indicating a prolonged spawning period for the cyprinids in this group, as larvae 7 mm long were probably hatched 2 wks prior to their capture.

Total number and concentration of unknown cyprinids entrained during August were low (see Figs. 118, 124) as the peak entrainment period had passed, indicating attainment of a large enough size and a change in behavior such that few larvae were vulnerable to being entrained. Sizes of larvae entrained, contrary to results observed in July, were comparable to sizes of larvae observed in field collections at beach stations in Pigeon Lake (Fig. 118).

A number of cyprinid fry (greater than 25.4 mm) were also collected in our larvae nets at a number of stations in Pigeon Lake and Lake Michigan (Appendix 11). Fry were caught at Pigeon Lake beach stations T and V on 7 July, 16 August and 1 November and at Lake Michigan station A (1.5 m - s.) on 21 July. Efforts at identifying these fry will be made for future reports.

Yellow Perch

Yellow perch are an important sport fish both in this part of Lake Michigan and in Pigeon Lake. Any assessment of potential effects of the Campbell Plant upon yellow perch requires an understanding of the temporal and spatial distribution of yellow perch in both habitats. Knowledge of entrainment mortality is also required for such an assessment.

Larval fish sampling in Pigeon Lake and Lake Michigan commenced on 31 May 1977 and continued through December. The pattern of yellow perch abundance was complicated by the presence of multiple-aged cohorts which originated from an early spawning (late April-May) in Pigeon Lake and a later spawning (late May-early June) in Lake Michigan. Our evidence suggested that these cohorts mixed in Pigeon Lake due to inflow of Lake Michigan water during plant operation. Thus entrainment samples contained larvae from both water bodies for at least part of the year.

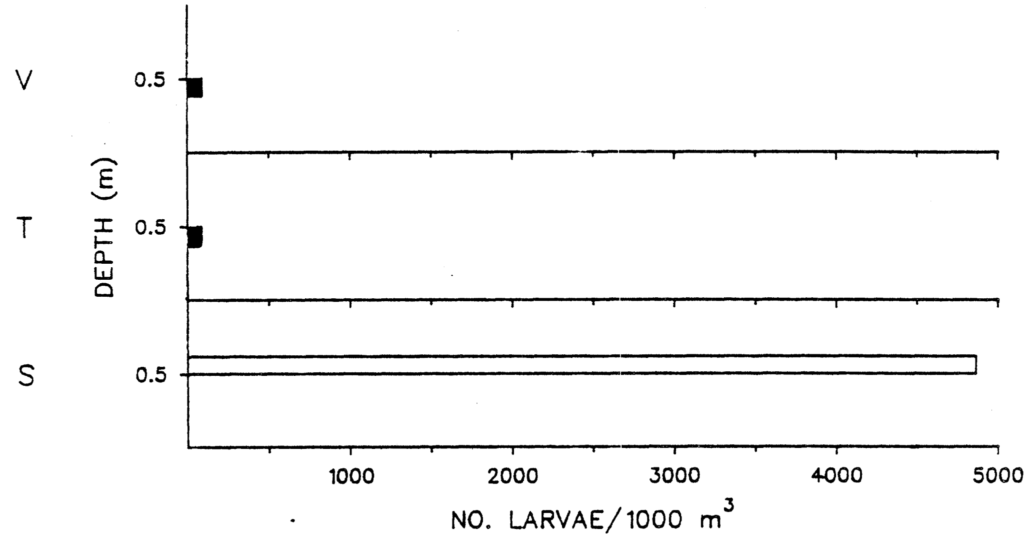


FIG. 125. Number of unidentified cyprinid larvae per 1000 m^3 for beach stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 15-19 August 1977. □ = Day ■ = Night

Pigeon Lake perch larvae were probably entrained during May, while Lake Michigan larvae were entrained during June.

Our hypothesis was based upon the 1977 data as well as preliminary analysis of 1978 entrainment data. In early June 1977 a wide range of length classes of larvae was found in Pigeon Lake. In general, perch larvae were more abundant and larger in the shallower, more remote areas of Pigeon Lake. Larvae were less abundant and smaller in samples collected at deeper stations and at those influenced by the flow of Lake Michigan intake water through Pigeon Lake. In contrast, no perch larvae were found in Lake Michigan samples in early June. By late June however, small yellow perch larvae were very abundant in Lake Michigan but nearly absent from Pigeon Lake except at deep stations near the plant intakes. Small larvae, similar in size to those present in Lake Michigan, were entrained 5 July 1977 indicating that mixing occurred. Finally, preliminary analyses of 1978 entrainment and field data clearly indicated two distinct pulses of perch larvae. Small perch larvae (5-8 mm) were entrained in large numbers in mid-May. Length ranges of perch from entrainment samples closely corresponded to the range observed in Pigeon Lake and no larvae were found in Lake Michigan samples. Another pulse of yellow perch larvae occurred in entrainment samples in mid-June but these larvae undoubtedly came from Lake Michigan. Length ranges of entrained perch and those from Lake Michigan samples were nearly identical.

Two other factors which obscured our interpretations of yellow

perch larvae distributions were gear avoidance and behavioral changes. Numerous authors (Faber 1967, Ward and Robinson 1974, Isaacs 1964) have noted the ability of yellow perch to avoid nets during the day. Similarly, Jude et al. (1975) observed no perch greater than 8 mm in their Lake Michigan larvae samples. Light intensity appears to be a major factor in avoidance since daytime catches of larval yellow perch, although lower than nighttime catches, generally increased with depth. As noted by Forney (1971) and Noble (1970) larval yellow perch undergo a marked change in behavior which should reduce their vulnerability to entrainment. The behavioral change consists of switching from a pelagic to demersal existence. Following this change, perch larvae remain close to cover (e.g. plants and rocks) to avoid predators. Concomitant with this behavioral change is rapidly increasing swimming speed (Houde 1969) which enables the larvae and fry to resist intake currents. Thus, the effects of gear avoidance, behavioral changes, dual spawning times and mixing of Lake Michigan and Pigeon Lake waters must be considered when examining the seasonal catch/effort data. These data are discussed in the following paragraphs.

A broad range of length classes of yellow perch larvae (6-30 mm) were observed in early June (1-3) in Pigeon Lake samples (Fig. 126). Larvae were caught at beach stations S (influenced by Lake Michigan) and T (influenced by Pigeon River) and all openwater stations M (6 m), X (2 m) and Y (1.5 m) (Fig. 127). High densities (2820/1000 m^3) of relatively large larvae (15-24 mm) were observed in the undisturbed shallow habitat of beach station T. Larvae taken from nearby openwater station Y (influenced by Pigeon River) had a similar range of lengths but were less abundant. A number of perch fry (25-30 mm) were also captured at both stations (Appendix 11). This habitat (stations Y and T, influenced by Pigeon River) was clearly the most favorable reproductive area within the Pigeon River - Pigeon Lake system. Protective cover was abundant in the form of macrophytes and debris. Early spring entry of warmer Pigeon River water and more rapid warming in this area than in other parts of Pigeon Lake or in Lake Michigan probably induced earlier spawning there by yellow perch. High numbers of larger larvae, fry and juveniles were captured at station T throughout our sampling program.

Perch larvae caught at station M (6 m - influenced by Lake Michigan) and beach station S (also influenced by Lake Michigan) in early June were around 6 mm. Since no larvae were captured in Lake Michigan at this time, these fish were probably hatched in Pigeon Lake rather than Lake Michigan.

In contrast to the total absence of perch larvae in Lake Michigan in early June, larvae attained peak abundance at Lake Michigan openwater stations (Fig. 128) during the late June (17-23) sampling period. The inferred late May-early June spawning time near the Campbell Plant was

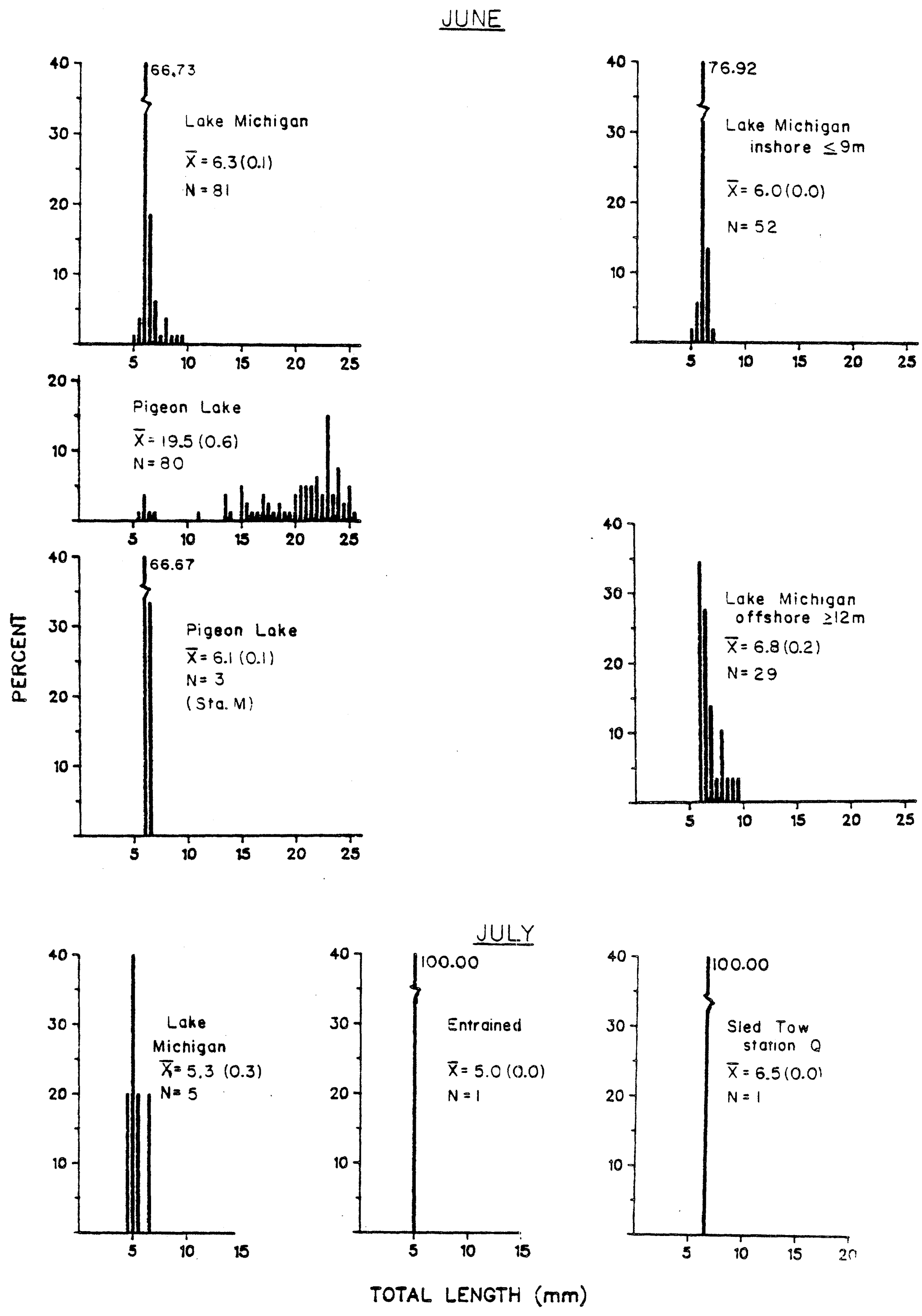


FIG. 126. Length-frequency histogram for larval yellow perch caught at selected pooled stations in Lake Michigan and Pigeon Lake near the J.H. Campbell Plant, 1977. All tows were net tows unless sled tows were specified. Inshore means all stations 3m or less in depth. ($\overline{X}$=mean, N=total number of larvae used in the comparison, standard error is given in parenthesis.)

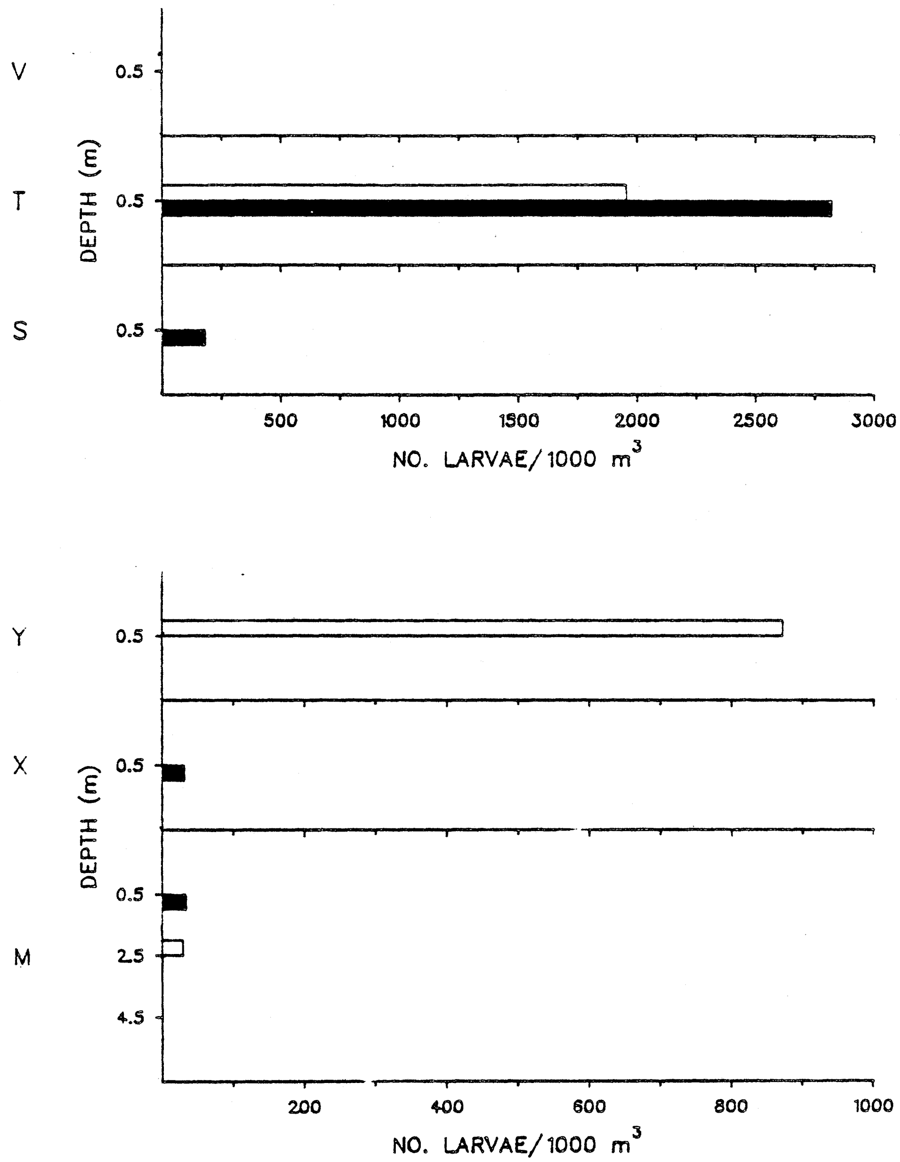


FIG. 127. Number of yellow perch larvae per 1000 m^3 for beach and openwater stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 31 May - 3 June 1977. □ = Day ■ = Night

similarly reported by Jude et al. (1975) during 1973 studies in southeastern Lake Michigan. At Campbell, larvae were most abundant at the 6, 9 and 12 m stations in Lake Michigan; few were taken at 3 m or depths greater than 12 m and none were caught at beach stations. Jude et al. (1975) noted a similar absence of perch at beach stations at the Cook Plant. No definite vertical distribution pattern (Fig. 127) was

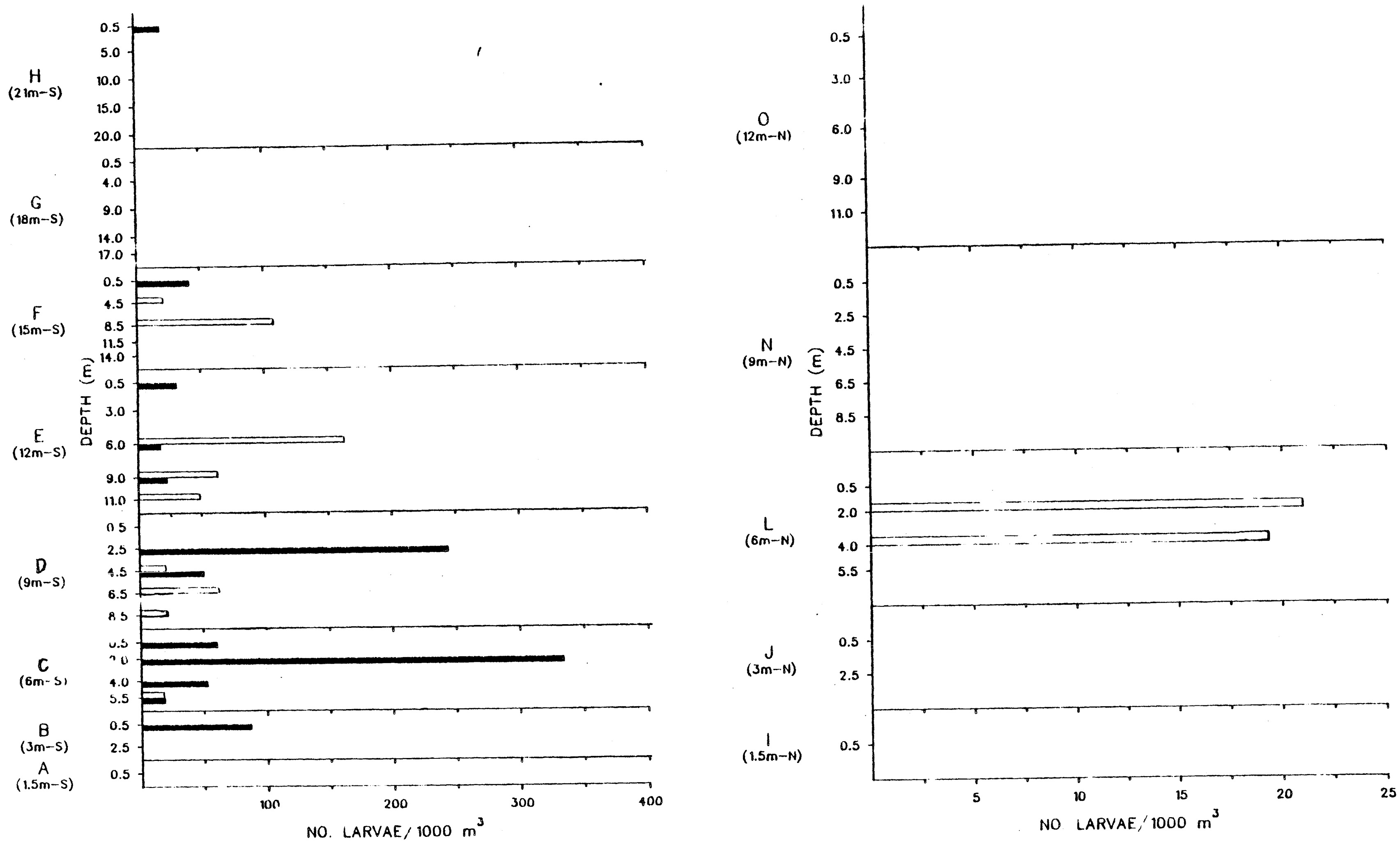


FIG. 128. Number of yellow perch larvae per 1000 m^3 for openwater Lake Michigan stations near the J. H. Campbell Plant, eastern Lake Michigan, 17-23 June 1977. □ = Day ■ = Night

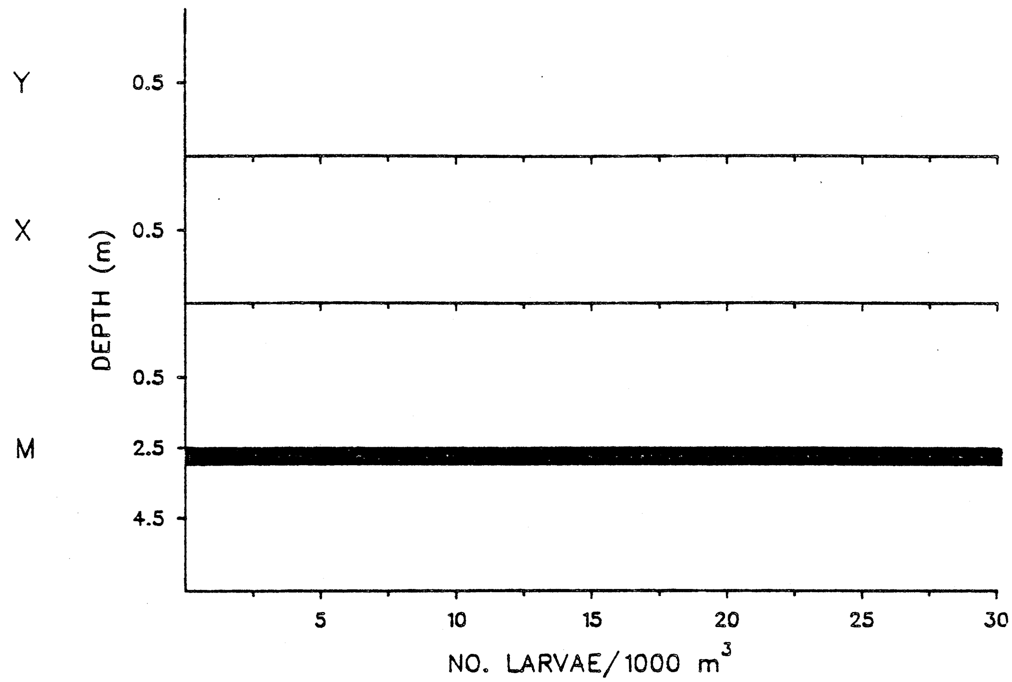


FIG. 129. Number of yellow perch larvae per 1000 m^3 for open-water Pigeon Lake stations near the J. H. Campbell Plant, eastern Lake Michigan, 17-23 June 1977. □ = Day ■ = Night

evident although more were caught at the deeper strata of the 9-15 m stations during the day than at any other strata. Ability of larvae to avoid a net may decrease with depth. At night, larvae were concentrated near the surface (Jude et al. 1975).

No larvae were caught in Pigeon Lake during the 17-23 June sampling period except at station M (6 m - influenced by Lake Michigan) (Fig. 129). These larvae were similar in size (6-9 mm) to those found in Lake Michigan and were thought to have been derived from there (Fig. 126). The apparent absence of yellow perch larvae in Pigeon Lake was undoubtedly due to gear avoidance and rapid growth from the larval stage. Presence of 32-40 mm fry in samples collected with plankton nets at station T supported this observation. Perch fry concentrations up to 1379/1000 m^3 were observed at station T (Appendix 11).

In Lake Michigan, yellow perch densities (17-391/1000 m^3) were much lower during the 7-13 July sampling period than in late (17-23) June. Perch were collected only four times during this July period. They were collected three times along the south transect (stations H - 21 m, E - 12 m and C - 6 m) (Fig. 130) and once along the north transect at station I (1.5 m) (Fig. 131). More larvae were caught at night than during the day, and no depth stratification of larvae was apparent. The

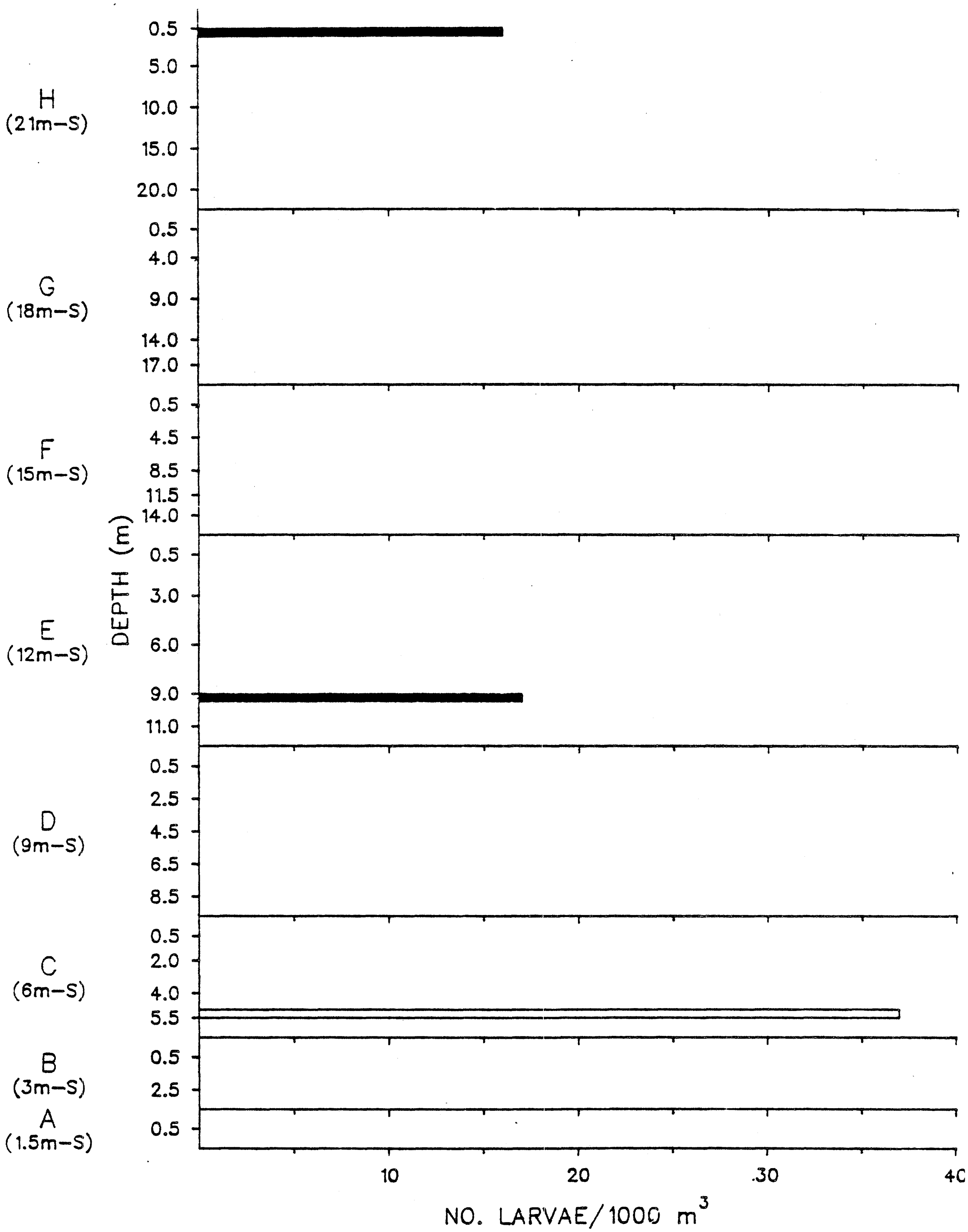


FIG. 130. Number of yellow perch larvae per 1000 m^3 for south transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 7-10 July 1977. □ = Day ■ = Night

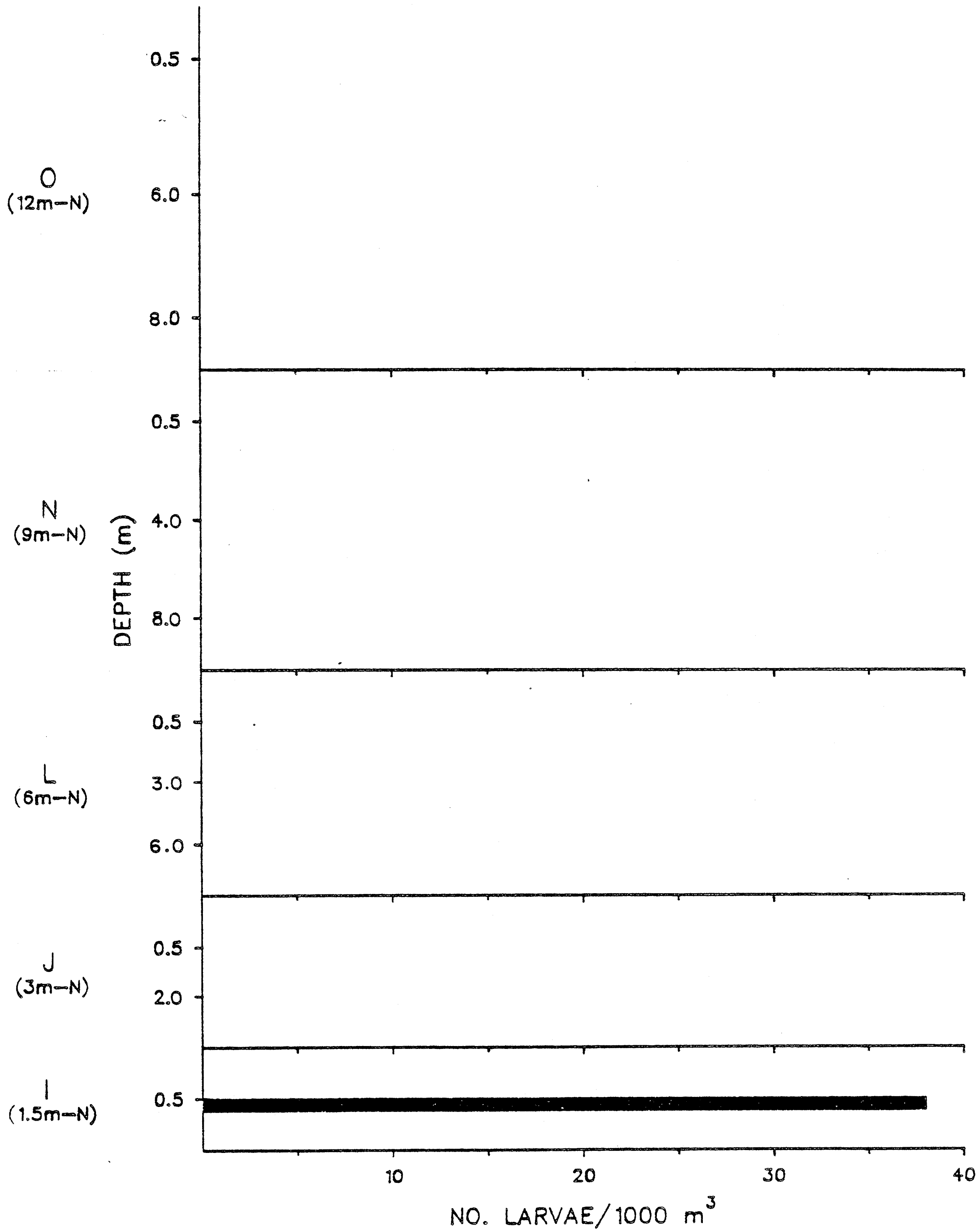


FIG. 131. Number of yellow perch larvae per 1000 m^3 for north transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 13 July 1977. □ = Day ■ = Night

range of lengths of Lake Michigan perch (4.5-6.5 mm) corresponded to the range of lengths for larvae entrained at this time which clearly indicates withdrawal of Lake Michigan water by the plant. Interestingly, larvae (17/1000 m^3) were found at the 21 m contour, but only in the epilimnion. No perch larvae this size (4.5 - 6.5 mm) were caught in Pigeon Lake during 7-13 July.

Rapid growth of yellow perch larvae in Pigeon Lake was evident during the mid-July (7-13) sampling period. Only yellow perch fry were caught and all were collected at station T, the preferred habitat. Fry, averaging 34 mm were caught there in moderate densities at night (average 80/1000 m^3) on 7-13 July. By 26 July, this cohort was 53-61 mm and was found at beach stations T and S. Yellow perch fry were only collected three more times for the remainder of the year, all in Pigeon Lake on 16 August at station V (68 mm), on 17 October at station T (70-80 mm) and on 1 November at station T (81-85 mm).

About 160 yellow perch larvae were collected in Lake Michigan and Pigeon Lake. Most were taken from upper water strata, indicating their preference for surface waters during their early planktonic stage (6-8 mm). One larva, however, 6.5 mm was collected during July in a sled tow at Lake Michigan beach station Q (s. discharge). In addition to being the only yellow perch larva caught in a sled tow, it was also the only one caught at a beach station in Lake Michigan.

Centrarchidae Complex

Since there are seven species of centrarchids in Pigeon Lake, and early stages of these larvae are difficult to identify, we included all known species and taxonomic groups (*Lepomis* spp. and *Pomoxis* spp.) under this discussion. Among the sunfishes there are green sunfish, pumpkinseed and bluegill. The warmouth, another *Lepomis* adult present, if collected never were identified in the larval form. Among *Pomoxis* spp., there are the black crappie which we collected as adults from Pigeon Lake and the reported presence of white crappie (Consumers Power Company 1975). There are two *Micropterus* present, the smallmouth and largemouth bass. In addition rock bass, *Ambloplites*, was also collected as adult and larva.

Pumpkinseed--

One pumpkinseed larva (12.1 mm) was collected at night on 26 July in a surface sample at beach station S (influenced by Lake Michigan). Water temperature was 15.6 C. (See unidentified *Lepomis* spp. for a discussion of *Lepomis* larvae which may include pumpkinseed).

Scarcity of pumpkinseed larvae in Pigeon Lake was surprising. Adults with developed gonads were collected and the shallow vegetated

areas would seem to be suitable spawning habitat. If pumpkinseed do successfully spawn in Pigeon Lake, the young must reside in areas relatively protected from sampling efforts, such as near the bottom in densely vegetated areas or many of the larvae, designated *Lepomis* spp., were pumpkinseed.

Green Sunfish--

Five green sunfish larvae (16.5-20.5 mm) were collected at night on 28 July at openwater station X (undisturbed Pigeon Lake). Larvae were collected from surface waters when the water temperature was 18.0 C; density was 155 larvae/1000 m^3.

Green sunfish spawn from mid-May to early August with multiple spawning occurring (Scott and Crossman 1973). Eggs hatch in 3-5 days. Nests are built in shallow, sunlit water in areas sheltered by rocks, logs, etc. The green sunfish larvae had probably moved off the spawning grounds by the time of collection and into the deeper water of station X, a phenomenon noted by Faber (1967) for sunfish larvae. Some of the *Lepomis* spp. larvae may have been green sunfish.

Largemouth Bass--

Largemouth bass are one of the important predaceous sport fish found in Pigeon Lake. Adults comprised almost 4% (760 fish) of the total number of fish captured in Pigeon Lake (Table 14). None were taken in Lake Michigan.

Twenty larval bass were collected during the study, all in Pigeon Lake, and almost all at beach station T (influenced by Pigeon River) in the remote section of Pigeon Lake (Fig. 132). One was also captured at openwater station X (undisturbed Pigeon Lake). Larval bass were taken in the first series of samples collected on 1 June in both day and night samples at beach station T (day-558/1000 m^3; night-598/1000 m^3) (Fig. 132 and Appendix 8). Length range of these fish was 11-25 mm, indicating spawning had occurred at least 2 wks prior to our sampling, sometime in mid-May. On 23 June bass were again recorded in both day (268/1000 m^3) and night (459/1000 m^3) samples at station T. Lengths of larval bass at this time were 11-24 mm. The last sampling period in July, also recorded the presence of largemouth bass, again at station T at night in a density of 260/1000 m^3. Only one larva 11.4 mm was collected. Three largemouth bass fry (25.5,27.2 and 31.0 mm) were also observed at this station in late July.

The final collection of bass occurred during the day on 17 October at openwater station X when one specimen 20.5 mm long was collected; density was 25/1000 m^3 (Fig. 133). A 49.5 mm fry (Appendix 11) was collected on 18 October from a day sample at station T.

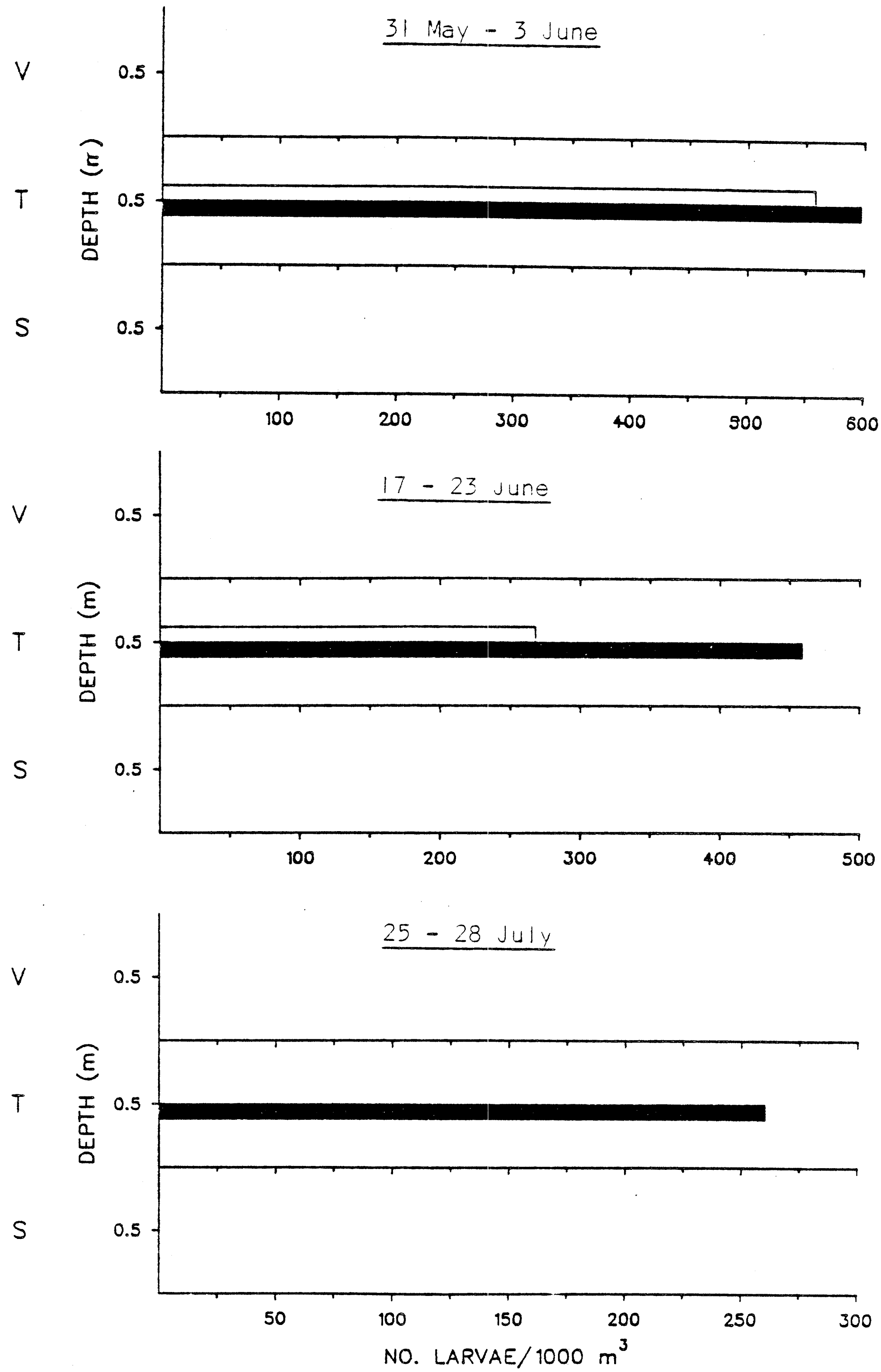


FIG. 132. Number of largemouth bass larvae per 1000 m^3 for beach stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 1977. □ = Day ■ = Night

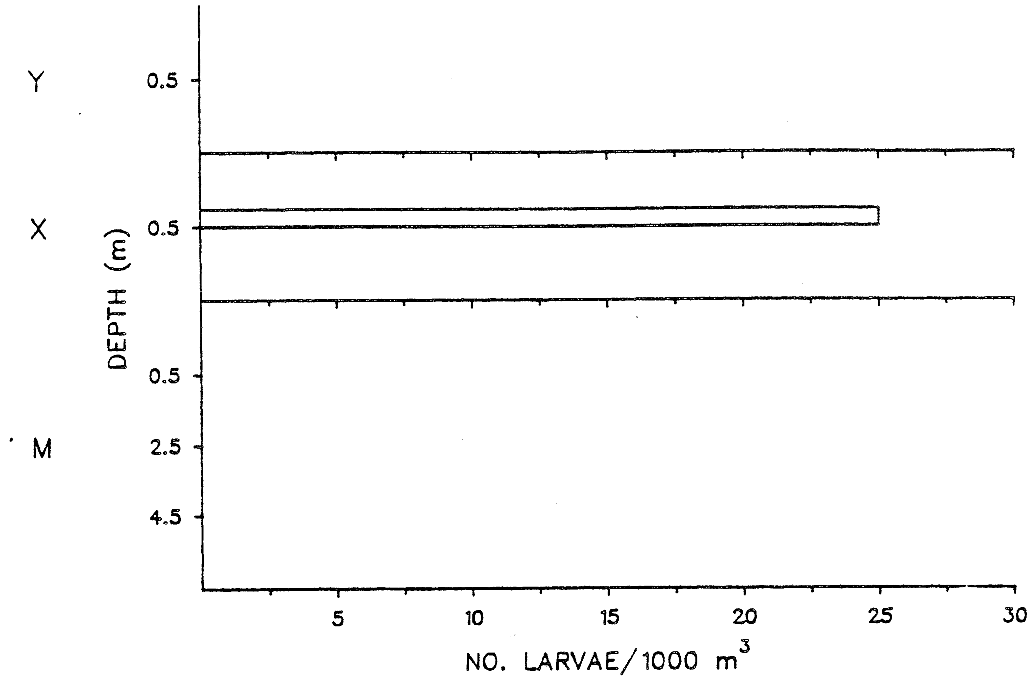


FIG. 133. Number of largemouth bass larvae per 1000 m^3 for open-water Pigeon Lake stations near the J. H. Campbell Plant, eastern Lake Michigan, 17-20 October 1977. □ = Day ■ = Night

Largemouth bass spawned sometime in May in Pigeon Lake and their larvae preferred the habitat represented by beach station T. This area is near the entry of Pigeon River with Pigeon Lake and was heavily vegetated and very turbid. This area is also highly productive and should be an ideal nursery for larval largemouth bass. Larval bass did not seem to move much from that area of the lake as most were caught there throughout the season. None were ever entrained. However, larvae captured were relatively large (greater than 11 mm); most other species of larvae entrained were considerably smaller, 5-8 mm.

Smallmouth Bass--

One smallmouth bass larva (10 mm) was collected in a night surface sample on 26 July at Pigeon Lake beach station S (influenced by Lake Michigan). The following information from Scott and Crossman (1973) suggested that smallmouth spawned in late June-early July in Pigeon Lake. Smallmouth bass spawn from late May to early July over a period of 6 to 10 days. Nests are built near rocks or logs for protection and occasionally near dense vegetation. Four to 10 days later larvae 5.6-5.9 mm hatch. Within 12 days larvae grow from 8.7 to 9.9 mm and rise from the bottom into the water column. The only large adult smallmouth captured was taken in a seine haul at night during June at beach station T (influenced by Pigeon River). However, absence of adult smallmouth from seine catches at beach station S, where the larva was

collected, does not preclude their presence, as water at station S was much clearer than at station T and net avoidance by large smallmouth would be expected there.

Rock Bass--

Rock bass were one of the less abundant adult fish collected in Pigeon Lake. We captured nine rock bass larvae during June and July at beach station T (influenced by Pigeon River) and openwater station X (2 m). In June eight rock bass (5-17.5 mm long) were obtained from station T. Larvae were taken in day surface samples on 1 June at a density of 186/1000 m^3, while at night densities were 342 larvae/1000 m^3. On 23 June day surface samples at station T contained 179 larvae/1000 m^3. On 28 July a single rock bass larva (24 mm long) was obtained from a surface sample at station X, resulting in a density of 31 fry/1000 m^3. Water temperature was 18.0 C.

Rock bass spawn in late spring and early summer in areas ranging from swamps to gravel shoals (Scott and Crossman 1973). This species spawns in May and June in weedy places along lake shores (Fish 1932). Beach station T (influenced by Pigeon River), being shallow and weedy, would appear to be a suitable spawning area for rock bass. Young rock bass are littoral to limnetic in habit which explains their occurrence at openwater station X in Pigeon Lake.

Black Crappie--

Black crappie larvae were only collected from day surface samples on 23 June at beach station T (influenced by Pigeon River). Water temperature was 24.4 C and larval density was 89 larvae/1000 m^3. More information on black crappie larvae, can be found under _Pomoxis_ spp., as most larvae with this designation are believed to be black crappies.

Black crappies spawn from late May to early July, beginning when water temperature is 19-20 C. Nests are built in water from 25-60 cm deep on a sand, gravel or mud bottom with some vegetation. Sometimes nests are built near undercut banks. Eggs hatch in 3-5 days (Scott and Crossman 1973). The vegetation, shallow water, and protective obstructions at station T would provide good spawning habitat for black crappies.

Unidentified _Lepomis_ spp.--

Lepomis spp. larvae (21) were collected in surface samples throughout the summer and once in October from stations in Pigeon Lake (S, T, V, Z) and beach station Q in Lake Michigan. One larva was entrained in August. Presence of very small larvae through August suggested that spawning of _Lepomis_ spp. occurred throughout the summer.

Length ranges in June, July and August were 5-11 mm, 8-14 mm and 4.5-19.9 mm, respectively. Based upon adult fish collections the unidentified larvae were most likely either pumpkinseed or bluegill. Lack of suitable spawning habitat in Lake Michigan strongly indicated that all Lepomis larvae originated from Pigeon Lake or more likely the discharge canal.

Unidentified Lepomis larvae were first caught on 23 June in day samples from beach station T (influenced by Pigeon River) and the intake canal (station Z). Concentrations at these stations were 358 and 25 larvae/1000 m^3 respectively. On 7 July, larvae (48/1000 m^3) were collected at Lake Michigan beach station Q (s. discharge) at night. All other Lepomis larvae captured in July were collected in night samples from Pigeon Lake beach stations S (179/1000 m^3) and V (89/1000 m^3). Larvae were caught in day and night samples on 13 August at beach station V; concentrations ranged from 89 to 610 larvae per 1000 m^3. No unidentified Lepomis larvae were caught in September, but a single larva (22.5 mm long) was captured on 17 October at openwater station X (undisturbed Pigeon Lake), resulting in a density of 26 larvae/1000 m^3.

The only recorded entrainment of Lepomis larvae occurred in August at very low concentrations (2/1000 m^3). In general we found very little entrainment of species endemic to Pigeon Lake, except for bluntnose minnows.

Four species of Lepomis are known from the area: pumpkinseed, green sunfish, bluegill and warmouth (present but rare). These four species of Lepomis coexist in the littoral zone of many lakes (Werner and Hall 1976) and have similar spawning times and habitats (Scott and Crossman 1973). Therefore, our unidentified Lepomis larvae may represent any or all of the above species.

Unidentified Pomoxis spp.--

Two species of the genus Pomoxis may inhabit the study area, but we have captured only black crappie near the Campbell plant. Previous workers have observed white crappie in impingement samples. Pomoxis larvae were taken only in June and July. All field-caught larvae were captured at Pigeon Lake stations, except for a single (11 m) larva taken in a night surface tow at Lake Michigan station C (6 m - s.) (Fig. 134). This larva had probably originated in the discharge canal, as many adult and larval species have been observed there during 1978.

Pomoxis larvae were widely dispersed in Pigeon Lake on 1 June. Highest concentrations were observed at beach station T in both day (8751/1000 m^3) and night (8288/1000 m^3) samples (Appendix 8) (Fig. 135). Lower concentrations were found at openwater station X and the intake canal (Fig. 135). These larvae ranged from 4 to 17 mm (Fig. 136), which suggested that spawning began in late May.

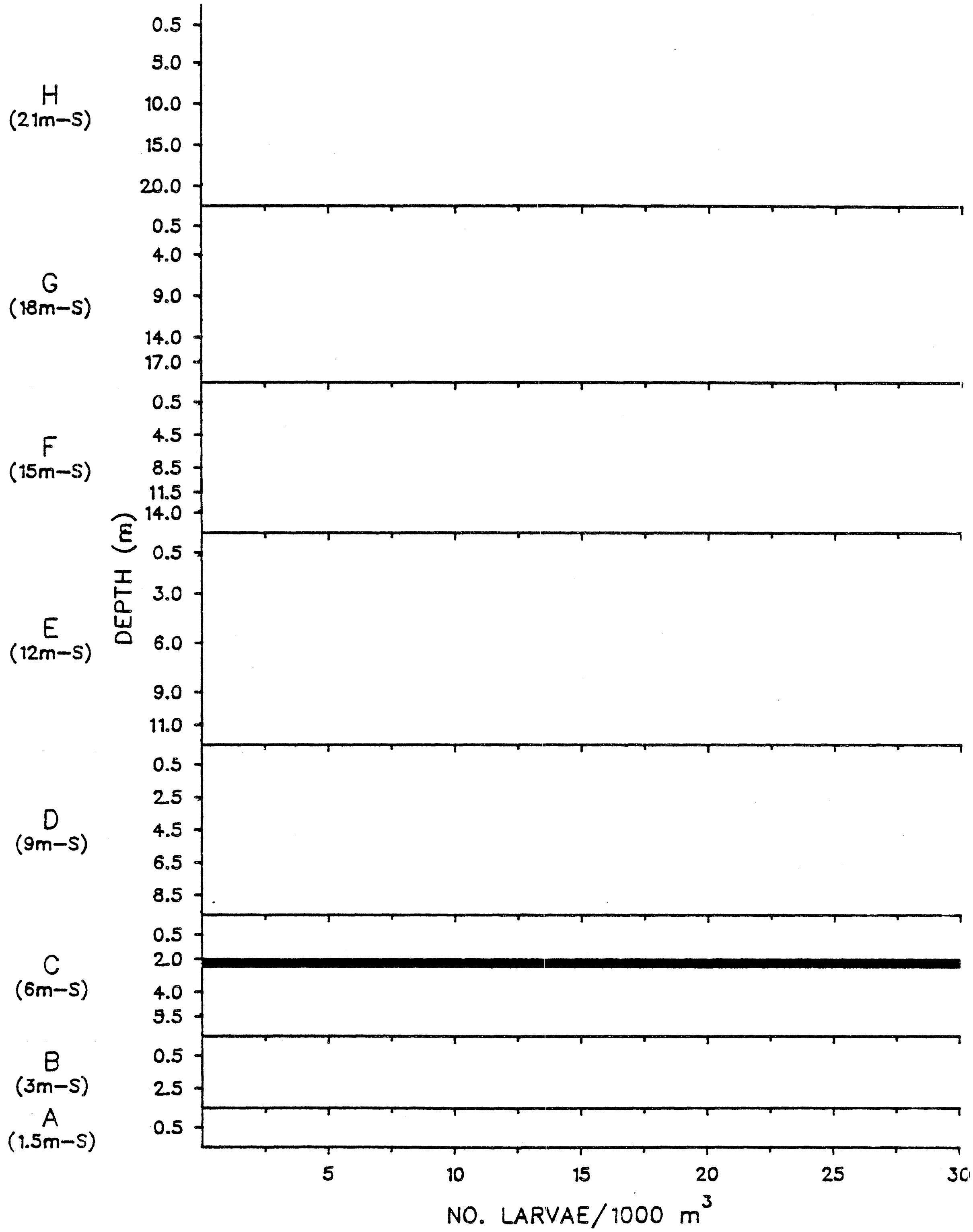


FIG. 134. Number of *Pomoxis* sp. larvae per 1000 m^3 for south transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 31 May - 3 June 1977. □ = Day ■ = Night

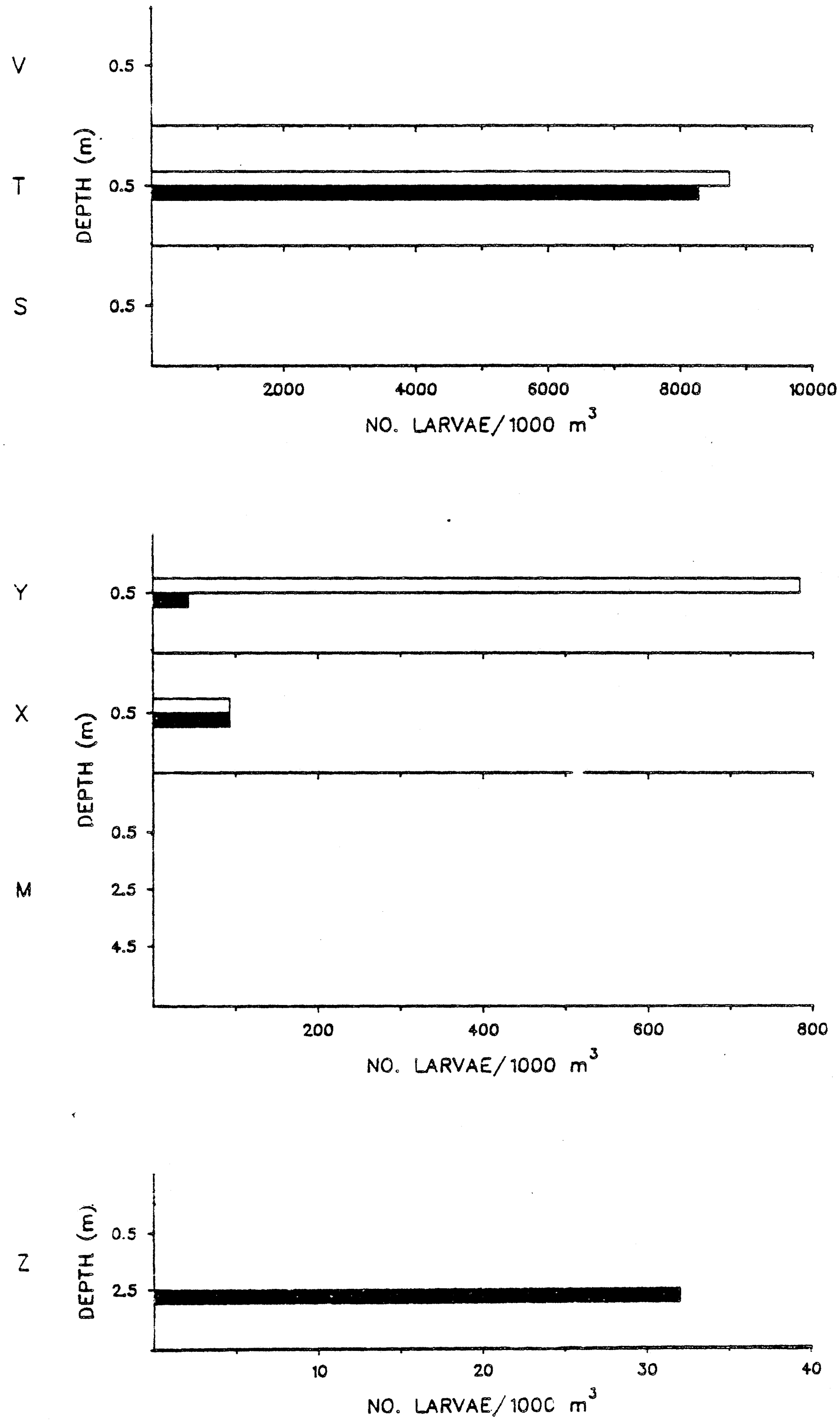


FIG. 135. Number of *Pomoxis* sp. larvae per 1000 m^3 for beach, openwater and intake canal stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 31 May - 3 June 1977. □ = Day ■ = Night

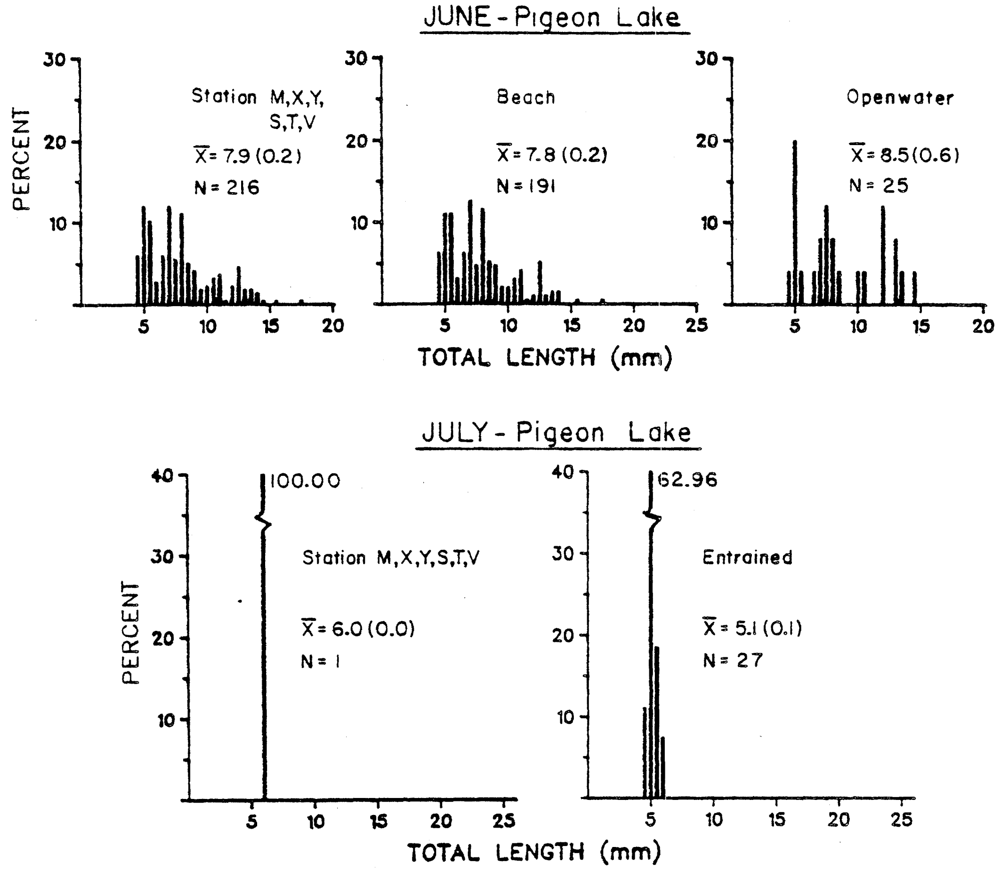


FIG. 136. Length-frequency histogram for larval *Pomoxis* spp. caught at selected pooled stations in Lake Michigan and Pigeon Lake near the J.H. Campbell Plant, 1977. All tows were net tows unless sled tows were specified. ($\overline{X}$=mean, N=total number of larvae used in the comparison, standard error is given in parenthesis.)

Only one larva, 6 mm, was captured in July field samples in a night tow at beach station V (undisturbed Pigeon Lake) (Appendix 8). Low numbers (4-30/1000 m^3) were entrained throughout July. These larvae were small (4-6 mm), recently hatched specimens originating from Pigeon Lake (Fig. 136).

Pomoxis larvae apparently grew rapidly since YOY black crappie, 30 to 60 mm, were abundant in July seine samples from Pigeon Lake. Absence of larger larvae from plankton net samples in July may be due to net avoidance.

Unidentified Centrarchidae --

One larva which we knew was a centrarchid, but could not identify to the genus level, was collected on 28 July at beach station V (undisturbed Pigeon Lake) during the day (Appendix 8). The larva was 11.0 mm and was caught when the water temperature was 23 C.

Bluegill Fry --

One bluegill fry (41.1 mm) was entrained on 19 September. In addition, one fry was collected in each of the following three field samples: on 22 September (42.0 mm) in a night sled tow sample at Lake Michigan station I (1.5 m - n.); on 17 October (32.0 mm) in a night surface sample at Pigeon Lake beach station T (influenced by Pigeon River); and on 18 October in a night surface sample at Pigeon Lake beach station S (influenced by Lake Michigan).

Bluegills spawn from late May to early August with a peak in June (Snow et al. 1970). Preferred habitats of this species are the shallow, weedy, warm areas of lakes, ponds and slowly flowing rivers. Pigeon Lake with its areas of dense vegetation and shallow water would provide ideal habitat for bluegill. The fry collected at Lake Michigan station I had probably moved into that area from more suitable habitat such as Pigeon Lake or perhaps the discharge canal.

Rainbow Smelt

The rainbow smelt, like the alewife, is an anadromous species which readily adapted to Lake Michigan. Although this species was one of the more common adult fish captured in the area of the Campbell plant, occurrence of larvae was relatively infrequent in the area during 1977 sampling, which unfortunately missed the spawning season. Rainbow smelt spawn in streams from March to May depending on locality and weather (Scott and Crossman 1973). Smelt also spawn along the beach on gravel shoals and this spawning may be as successful as stream spawning (Rupp 1965). Lake Superior smelt averaged 14,673 eggs per ounce of female (Bailey 1964). Eggs are 0.9-1.0 mm in diameter and hatch in 2-3 wks depending on temperature. Smelt larvae from the Miramichi River system, New Brunswick hatched in 29 days at 6.0-7.0 C, 25 days at 7.1-8.0 C and 19 days at 9-10 C (McKenzie 1964).

Smelt larvae in the area of the Campbell Plant were first observed at south transect stations in late June (Fig. 137). Smelt larvae were caught at depths from 15 m (station F - s.) to 21 m (station H - s.) with densities ranging from 0-141 larvae/1000 m^3. At night smelt larvae were caught in surface tows at all these stations; whereas during the day, smelt larvae were restricted to deeper strata. These data probably indicate a vertical diel movement by larvae of this species, toward the surface at night and toward the bottom during the day, which agreed with findings of Jude et al. (1979).

The small average size and narrow range of lengths observed in the June larvae samples (Fig. 138) suggested that these larvae were newly hatched. Net avoidance was not evident since length-frequencies of day and night catches were nearly identical (Fig 138). The cohort we

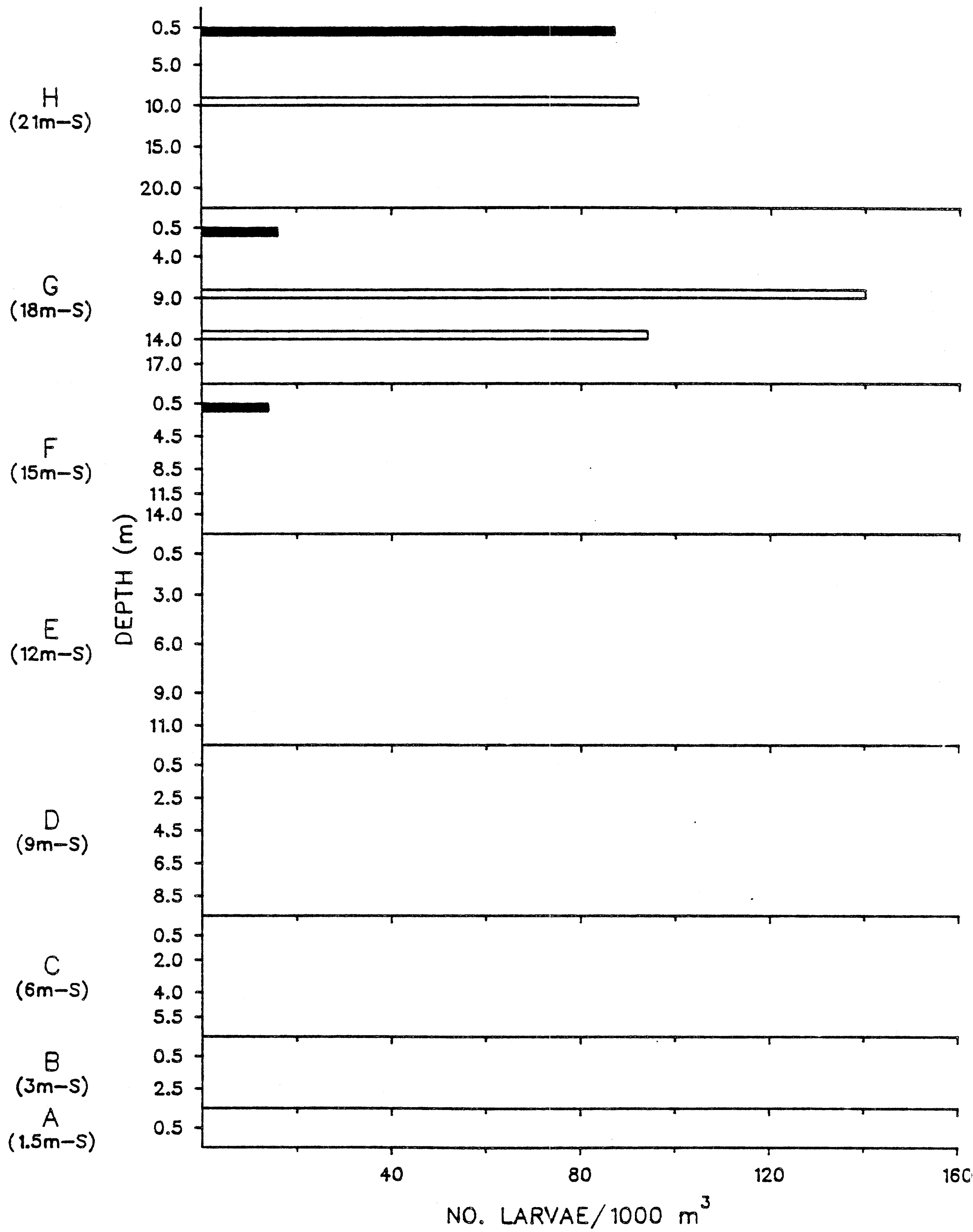


FIG. 137. Number of rainbow smelt larvae per 1000 m^3 for south transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 17-23 June 1977. □ = Day ■ = Night

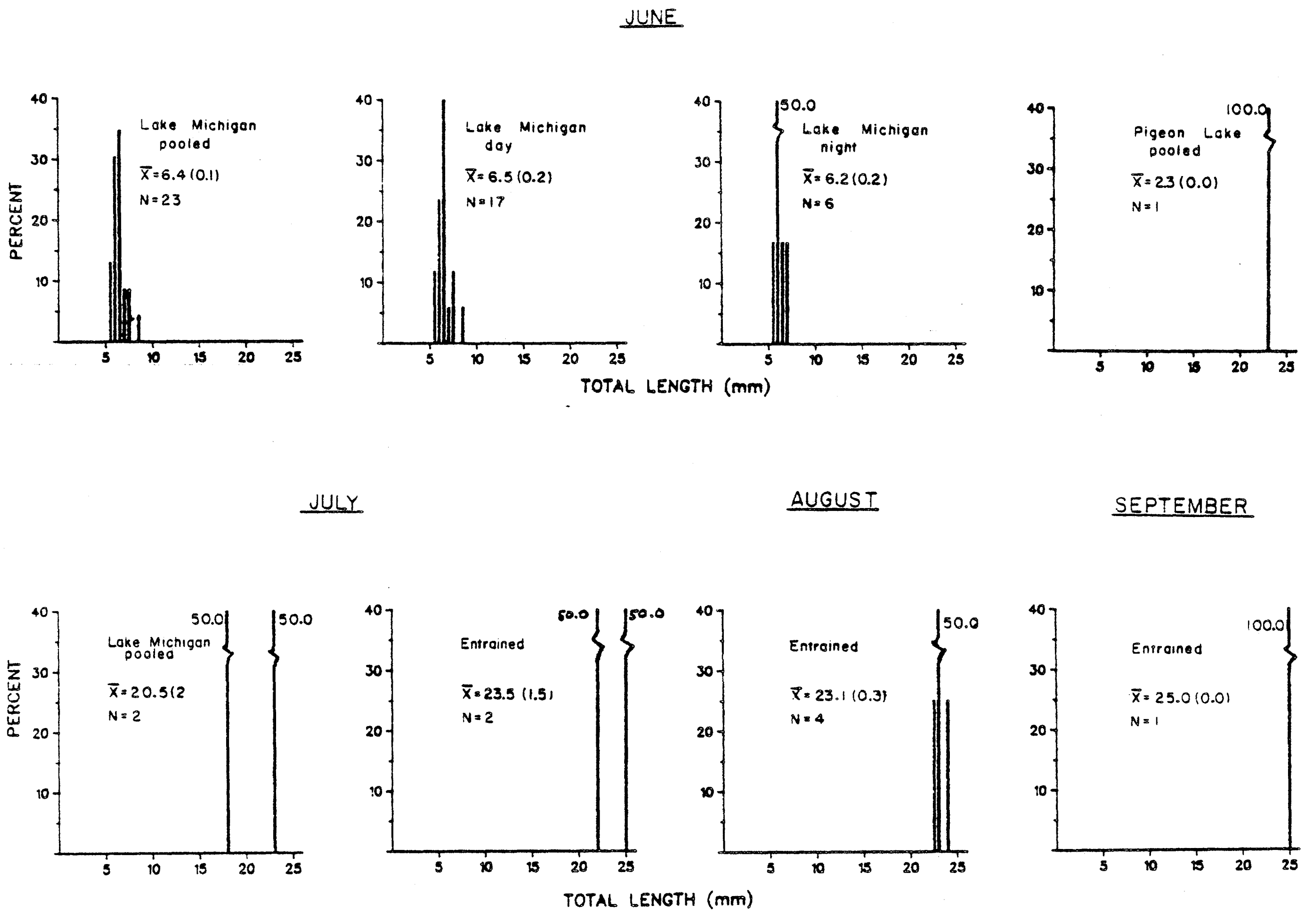


FIG. 138. Length-frequency histogram for larval rainbow smelt caught at selected pooled stations in Lake Michigan and Pigeon Lake near the J.H. Campbell Plant, 1977. All tows were net tows unless sled tows were specified. ($\overline{X}$=mean, N=total number of larvae used in the comparison, standard error is given in parenthesis.)

sampled in June was probably produced by a relatively small fraction of the spawning population in late May. An earlier, more intense spawning period was indicated by high numbers of YOY, 25-45 mm, which were trawled in late July. Growth data summarized by Scott and Crossman (1973) suggested these larvae were about 2 months old. Given this premise, absence of larger smelt larvae in June must be due to either net avoidance by larger larvae or immigration of YOY into the trawling depths during July

Only two additional occurrences of smelt larvae from July to November were observed at Lake Michigan stations. A density of 103 larvae/ 1000 m^3 was observed at station 0 (12 m -n.) in late July,

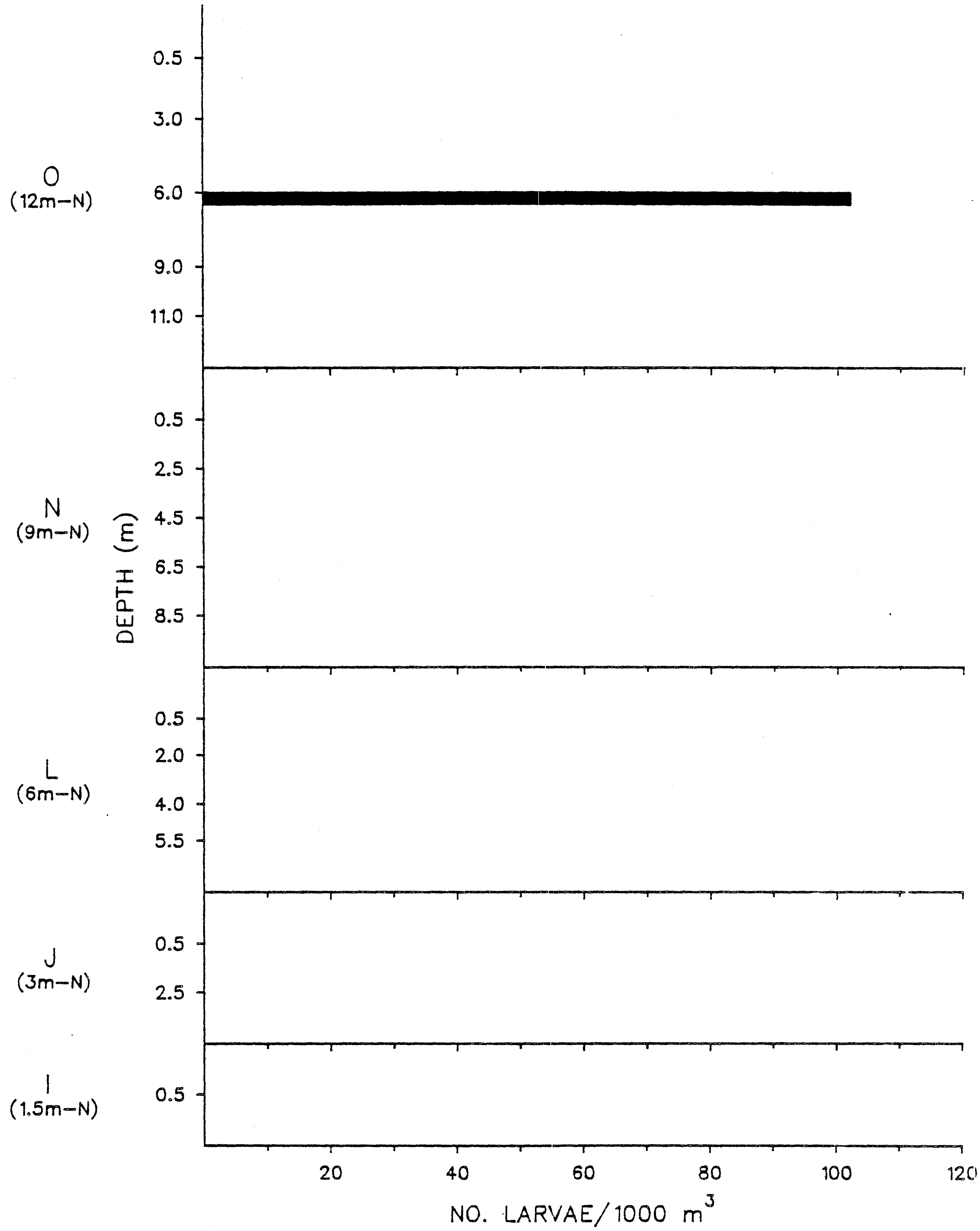


FIG. 139. Number of rainbow smelt larvae per 1000 m^3 for north transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 25-28 July 1977. □ = Day ■ = Night

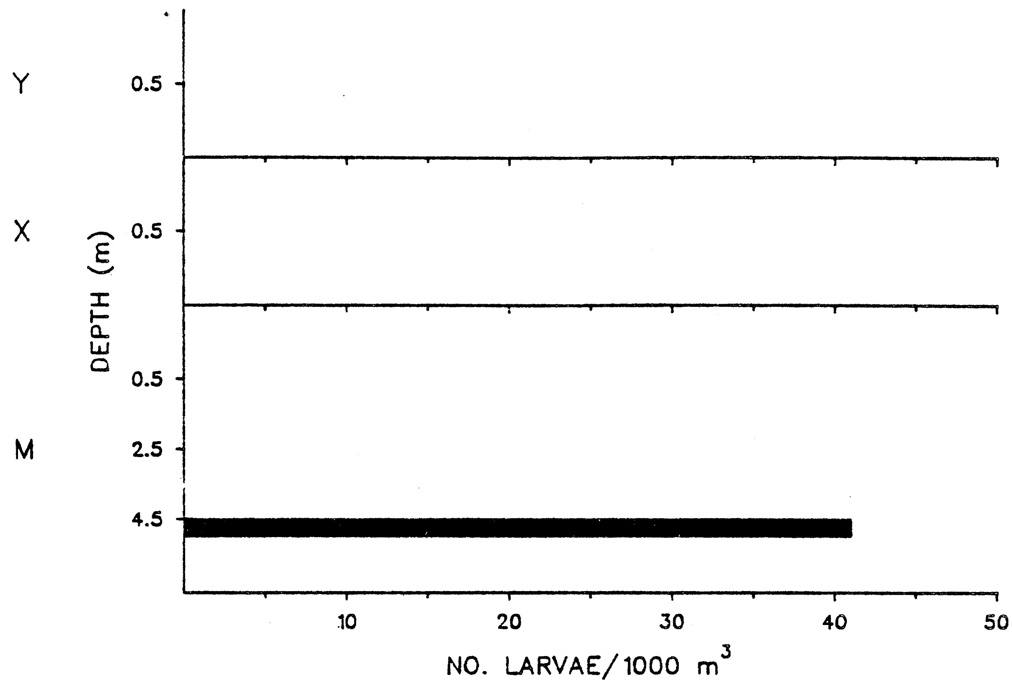


FIG. 140. Number of rainbow smelt larvae per 1000 m^3 for open-water Pigeon Lake stations near the J. H. Campbell Plant, eastern Lake Michigan, 17-23 June 1977. □ = Day ■ = Night

and a concentration of 30 larvae/1000 m^3 was observed in a sled tow sample at the same station in September. The two larvae observed in July at station 0 (12 m - n.) were 17 and 23 mm (Fig. 139), and probably hatched from eggs laid in early May. The one larva captured in a September sled tow was 25 mm, and was probably part of the smelt cohort spawned in late May.

The extent to which Pigeon River and Pigeon Lake were used by smelt for spawning cannot be determined using 1977 data. The only occurrence of smelt larvae in Pigeon Lake during 1977 was late June at 6 m openwater station M (influenced by Lake Michigan) when 42 larvae/1000 m^3 were observed at the 4 m depth at night. The 23 mm larva in this sample (Fig. 140), probably hatched in May possibly in Pigeon Lake. In general, absence of smelt larvae in early June from Pigeon Lake, as well as lack of suitable spawning habitat gives initial indication that Pigeon Lake was not used for spawning by smelt. Data from 1978 may clarify this question.

Our data showed that growth of smelt larvae into the fry stage occurred primarily during August, when increased densities of fry were noted at most Lake Michigan stations (Appendix 11). No smelt fry were collected from Pigeon Lake in August. Most fry were captured at night; lack of fry in day samples was undoubtedly due to net avoidance.

In September, smelt fry were collected sporadically only at night in Lake Michigan (Appendix 11). Smelt fry were not caught in Lake Michigan during October which coincided with a decreased catch of adult smelt during this month (Appendix 11). Smelt probably moved from the area to deeper water at this time. Smelt fry were observed in low densities at Pigeon Lake openwater station M (6 m-influenced by Lake Michigan) and intake canal station Z where 26 and 32 fry/1000 m^3 respectively were collected during October.

Entrainment of smelt larvae by the Campbell Plant was low during 1977 sampling, not exceeding 2500 larvae/24 hr period during July-December (Fig. 141). Most larval entrainment occurred at night. This trend was similar to that of spottail shiner larvae and reflects an apparent increased vulnerability of fish larvae when they were found to migrate to surface water strata. All smelt larvae entrained exceeded 20 mm in length (Fig. 138). Although 1977 sampling indicated low entrainment of smelt larvae, we expect increased entrainment immediately following the spring spawning season.

Entrainment of smelt fry generally exceeded entrainment of larvae from 3 August to 21 November (Fig. 141). High numbers of smelt fry in entrainment samples in late summer, up to 40000/24 hr period, were probably due to immigration of fry from other areas into the influence of the intakes. Most entrainment occurred during the night hours with the exception of 1 and 8 September when entrainment during daylight hours exceeded nighttime entrainment. Entrainment of smelt fry after 8 September was sporadic with values ranging from zero to over 10,000 larvae entrained in a 24-hr period in early October.

Johnny Darter

Eight johnny darter larvae were collected during 1977; all were taken during early June in Pigeon Lake; seven at beach station T (influenced by Pigeon River) and one at beach station V (undisturbed Pigeon Lake)(Fig. 142). All larvae were collected at night from surface waters where water temperatures were 16.6 and 14.0 C, respectively. Replicate tows at station T at night revealed larval densities of 171-1026 larvae/1000 m^3. Larval density at station V was 79 individuals/1000 m^3.

Spawning by johnny darter takes place in spring with local conditions determining the exact time (Scott and Crossman 1973). Spawning occurs during May and June in southern Michigan (Winn 1958b), southeastern Lake Michigan (Jude et al. 1975) and Lake Erie (Fish 1932). Hatching time ranges from 5-8 days at temperatures of 22-24 C (Scott and Crossman 1973) with newly hatched larvae measuring 5.0 mm total length (Fish 1932). Larval lengths from beach stations T and V ranged from 12.5 to 22.5 mm indicating spawning had occurred sometime

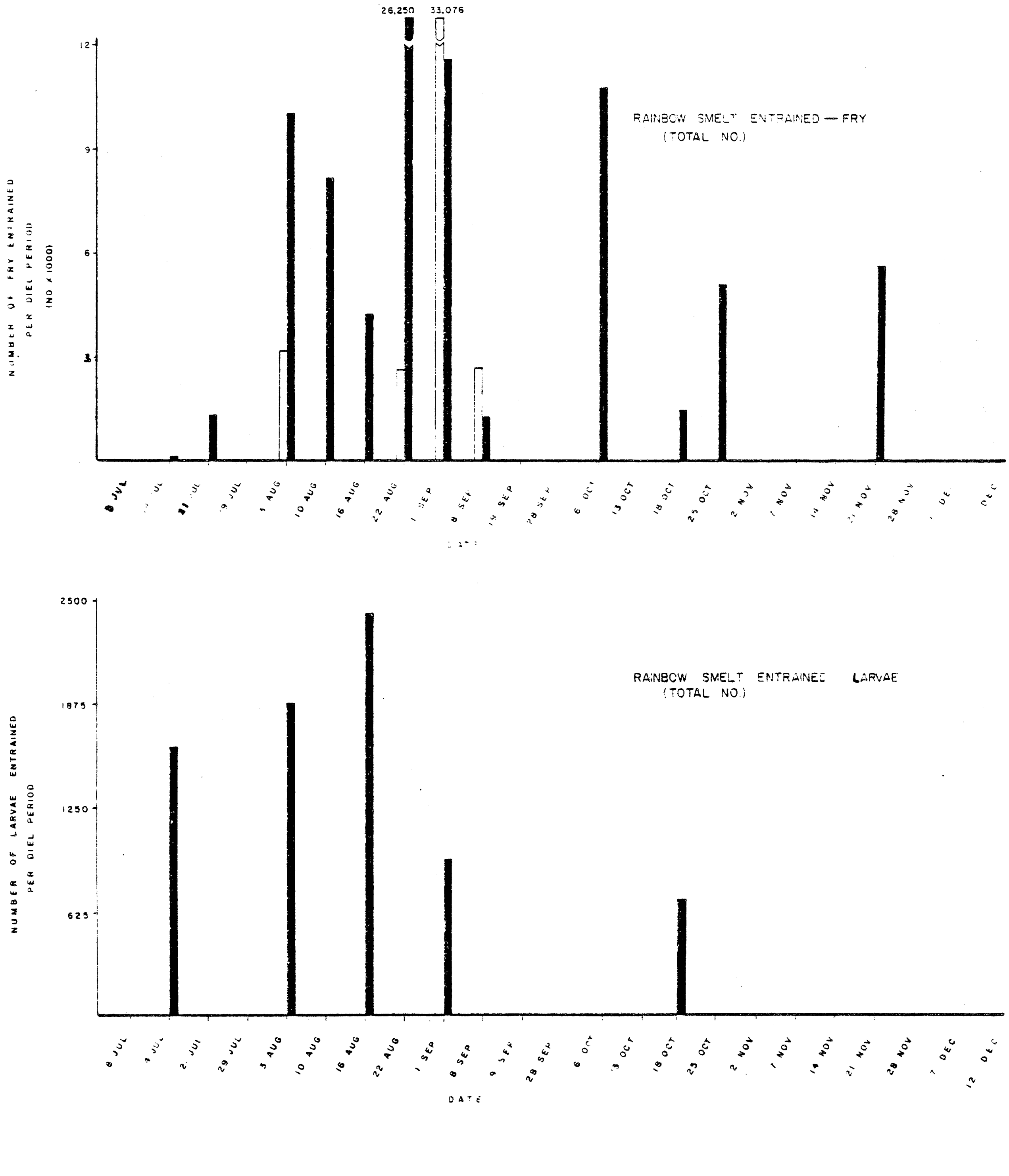


FIG. 141. Total number of larval rainbow smelt entrained during the day and night at the J.H. Campbell Plant, 1977.

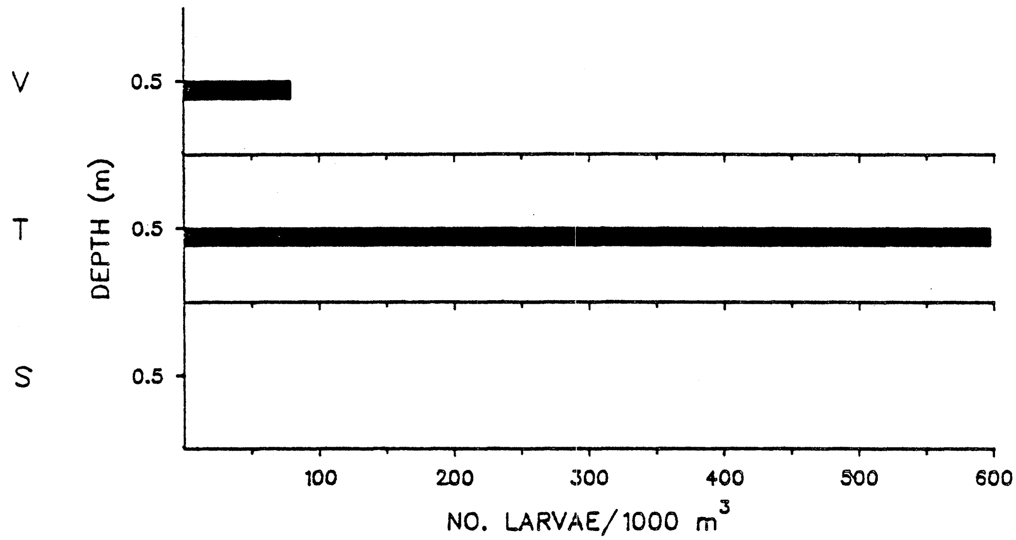


FIG. 142. Number of johnny darter larvae per 1000 m^3 for beach stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 31 May - 3 June 1977. □ = Day ■ = Night

prior to 1-2 June near the Campbell Plant.

Johnny darters inhabit a wide range of aquatic habitats, but are usually found in inshore waters of moderate or no current (Scott and Crossman 1973). They spawn in areas having large rocks, logs or other objects under which they can deposit eggs (Winn 1958b). Beach station T (influenced by Pigeon River), with shallow water and large obstructions present satisfies these requirements.

Four unidentified Etheostoma larvae were collected, all in night surface samples. On 1 June 1977 one (9.5 mm total length) was taken at Pigeon Lake beach station S (influenced by Lake Michigan) at a temperature of 11.0 C. On 2 June two (12.0 and 12.5 mm) were collected at openwater station X (undisturbed Pigeon Lake) at 10.3 C. One Etheostoma spp.larva (7.0 mm) was also entrained in July.

Brook Silverside

Fewer brook silverside larvae were collected (total of 22) than was expected, considering adults were the 11th most abundant adult fish captured in Pigeon Lake. Ten larvae, with a length range of 4.5 to 18.5 mm, were observed in June at beach stations T (influenced by Pigeon River) and V (undisturbed Pigeon Lake). Twelve were collected in July at station T; lengths ranged from 9-15.1 mm (Fig. 143).

Silversides showed their preference for the weedy, somewhat more turbid, remote section of Pigeon Lake. Samples from beach station V (undisturbed Pigeon Lake) at night on 23 June at the surface (20.0 C)

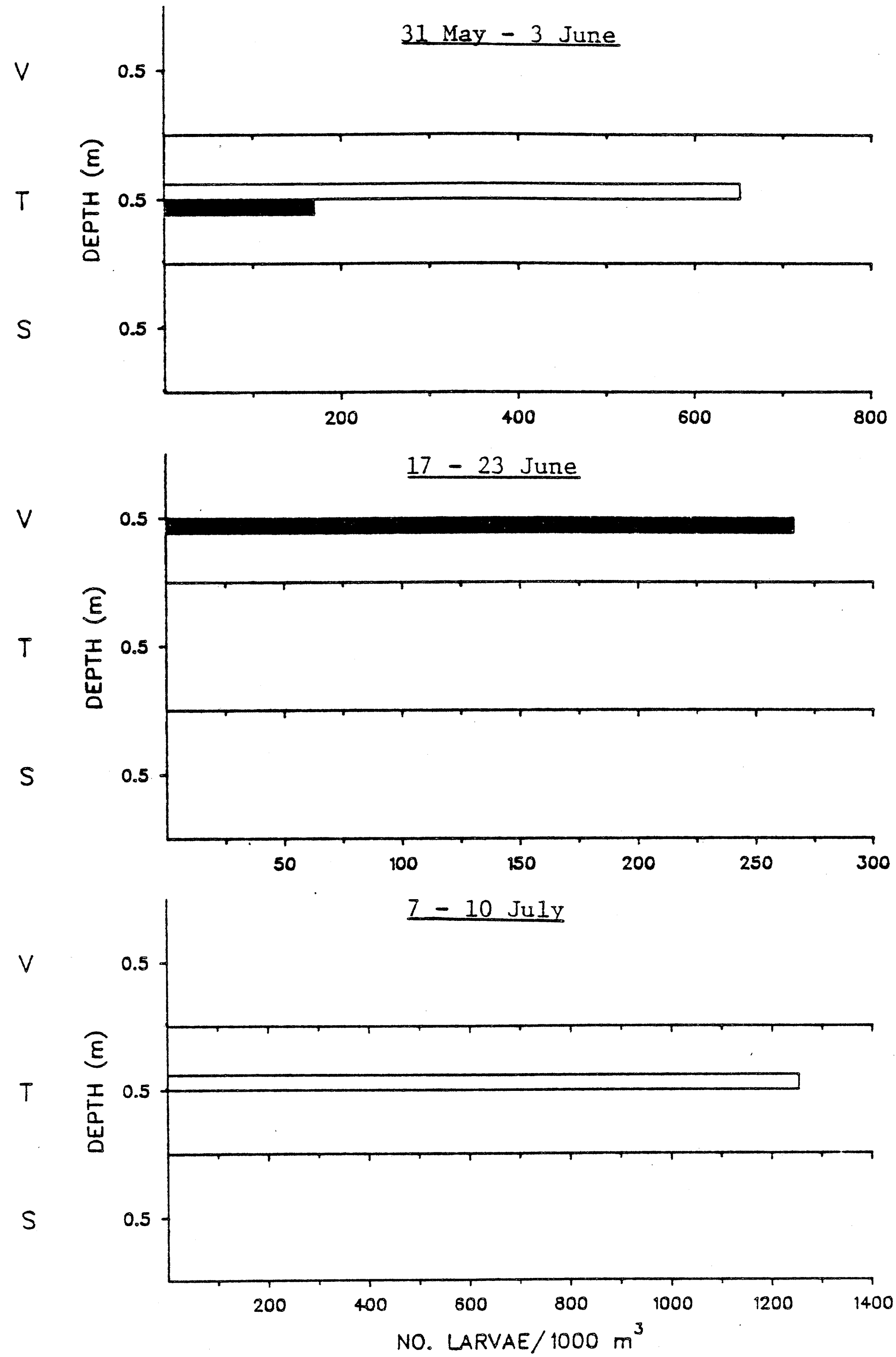


FIG. 143. Number of brook silverside larvae per 1000 m^3 for beach stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 1977. ☐ = Day ■ = Night

contained 266 larvae/1000 m^3. This station also contained considerable amounts of vegetation. None were collected at the somewhat less vegetated, sand-bottom station S (influenced by Lake Michigan). At station T on 1 June larval densities of 651/1000 m^3 were found in day surface samples when the water temperature was 12.0 C. Night surface samples (16.6 C) showed a mean density of 171 larvae/1000 m^3. The July sample was taken from surface waters at 16.6 C at station T during the day and showed 1254 larvae/1000 m^3--a high concentration of larvae (Fig. 143).

Scott and Crossman (1973) reported that spawning by brook silversides occurred in spring and early summer. In a northern Indiana lake, spawning extended from 17 June to 5 August (Nelson 1968a). Silversides prefer to spawn in and around aquatic vegetation, although they may spawn over gravel in moderate current (Scott and Crossman 1973). Beach stations T and V are areas of dense vegetation and would afford good spawning conditions for this species.

Ninespine Stickleback

Ninespine stickleback larvae (9) were all collected during June in Pigeon Lake surface tows at beach station S (influenced by Lake Michigan). They ranged in length from 9 to 20.5 mm. They were taken on 1 June during both day and night sampling. The surface day tow replicates (water temperature 11.2 C) showed an average larval density of 281 larvae/1000 m^3 (Appendix 8). The night tow (temperature 11.0 C) revealed a density of 537 larvae/1000 m^3.

Reported spawning time for this species ranged from April to August (Nelson 1967, Scott and Crossman 1973) with greatest spawning activity occurring at 11-12 C (Griswold and Smith 1972). Average total length at hatching (12 C) was 5.65 mm with lengths of 5.95, 7.56 and 12.91 mm after 1, 11 and 22 days respectively (Griswold and Smith 1972). Ninespine stickleback larval lengths in June at beach station S ranged from 7.5 to 20.5 mm indicating that spawning was probably initiated sometime in late April-early May and had been occurring over a period of weeks (see ADULT AND JUVENILE FISH - Ninespine Stickleback).

Station S, where all larvae were caught, has a fine sand bottom with sharply increasing depth. Griswold and Smith (1973) reported large concentrations of both male and female sticklebacks in beach areas with steep slopes covered with dense growths of Nitella sp. McKenzie and Keenleyside (1970) in a South Bay, Manitoulin Island, Ontario study, described spawning habitats as rocks and gravel with no rooted plants in the nesting area. Loose mats of detritus and plant fragments were found on nearby sandy bottoms. Nelson (1967) suggested that this species moved from deep water into rooted aquatic plants to spawn in the spring and after spawning moved back into deeper water. After hatching, young fish scatter along the bottom and hide among rocks.

Three unidentified stickleback larvae were also collected in night samples. Two larvae (8.5 and 9.0 mm) were collected on 28 July in a surface sample at station A (1.5 m - s.) in Lake Michigan. Water temperature was 13.0 C. One additional stickleback larva (8.0 mm) was taken in July from a 2 m sample at openwater Pigeon Lake station M (influenced by Lake Michigan). Water temperature was 11.7 C. These larvae were probably ninespine stickleback because ninespines were the only adult sticklebacks collected during the study to date.

Slimy Sculpin

Three slimy sculpin larvae (total captured during 1977) were taken on 27 July at offshore Lake Michigan stations F (15 m - s.) and H (21 m - s.). A day sample from station F, at a tow depth of 15 m and water temperature of 4.8 C, contained a single larva (12 mm). Day and night samples at station H at tow depths of 9 m and 15 m, where water temperatures were 4.1 C and 6.5 C also contained one larva in each sample, 12.5 and 19.0 mm respectively. Collection of sculpins at 9 m at the 15 m station F indicates these larvae are found off the bottom on occasion.

Rottiers (1965) reported that slimy sculpin spawning in Lake Michigan began prior to 5 May in shallow water. By 23 May, almost all adult fish collected were spent. However, slimy sculpins collected from deep water had not yet spawned by 26 May. Larvae we collected were probably spawned in deep water also during May. In the Montreal River, spawning occurred at about 8 C in early May and eggs hatched after about 4 wks (Scott and Crossman 1973). Slimy sculpins spawned at depths from 17-45 fathoms with bottom types ranging from fine sand to mud (Rottiers 1965). When occupying a stream habitat, they attach their eggs to the undersides of rocks and logs. In Lake Michigan where such debris is lacking, their spawning behavior is largely unknown. However, eggs which subsequently hatched were collected by divers on intake structure riprap near the Cook Nuclear Plant, southeastern Lake Michigan (Jude et al. 1975).

Fourhorn Sculpin

Two fourhorn sculpin larvae (14.5 and 17.5 mm) were obtained in night samples on 18 August at station G (18 m - s.) in Lake Michigan. Water temperature was 15.1 C at 14 m and 4.7 C at 17 m where the larvae were collected. Minimum length of newly hatched larvae was 7.6 mm according to Kahn and Faber (1974), suggesting hatching sometime prior to August, probably April-May.

Little is known about the breeding biology of the fourhorn sculpin because it is a deepwater species on which little work has been done. Scott and Crossman (1973) suggested spawning occurs in summer or early

fall. Fish (1932) reported collecting larvae of this species from the end of July to mid-August in Lake Erie. Our recent experience in identifying fourhorn sculpin from other areas, specimens in GLRFLC, as well as capture records from the Cook Plant and Campbell Plant (unpublished data) suggests strongly that spawning occurs in winter. Later, these larvae become distributed widely in inshore waters.

Trout-perch

Trout-perch spawn in the spring, usually in May, in many inland waters. In Lake Erie, spawning was observed from May to August (Scott and Crossman 1973), while Magnuson and Smith (1963) found trout-perch in Red Lakes, Minnesota spawned from June through August. Trout-perch spawning in larger lakes (such as Lakes Michigan and Erie) is apparently prolonged over several months. Peak spawning periods are not evident and spawning appears to be uniformly distributed over the period. Hatching occurs within 20 days (Scott and Crossman 1973).

Although trout-perch were common in adult fish samples at the Campbell plant, only four larvae were collected. All four were taken at different times and locations. Our data suggested that spawning occurred at least from mid-June through September. A 15 mm larvae was captured in a sled tow on 21 July at Lake Michigan station F (15 m - s.) at a water temperature of 6 C. We estimated that this larvae was spawned about mid-June. One other larva captured on 21 July was a 6 mm specimen found in entrainment samples. Two larvae were also captured on 21 September in sled tows at stations J (3 m - n.) and L (6 m - n.). Lengths of these larvae were 6 and 10 mm respectively. Trout-perch larvae were usually found on the bottom and captured most frequently in sled tows. Spawning by trout-perch at both the Cook and Cambell plants appeared to be extended and intermittent.

Unidentified Coregonidae

One unidentified coregonid larva (13.0 mm) was taken in a day sample from the 4 m tow on 18 June at station F (15 m - s.), Lake Michigan. Water temperature was 13.5 C. We believe that this larva was a bloater, since C. hoyi is one of the common adult coregonids in this vicinity. Since considerable difficulty remains in identifying the small adult coregonids, the possibility of identifying their larvae remains remote. Larval bloaters collected by Wells (1966) in southeastern Lake Michigan ranged from 8.6 to 14.9 m, which further confirms our belief that the 13 mm specimen we caught was a bloater. Wells also found that larval bloaters were most abundant in June and July and were primarily found between 73-110 m, being rare at depths shallower than 36 m. Based on Wells' data, larval bloaters would be expected to be found in low numbers in the study area, because sampling was only conducted to 21 m. The larva captured probably hatched during

the mid-January to mid-March spawning season as found by Wells. These eggs probably incubated 4 months before hatching.

Unidentified Ictalurus spp.

One 15 mm bullhead larva was taken in a day tow in Pigeon Lake at beach station V (undisturbed Pigeon Lake) on 7 July. Water temperature was 28 C. There are five species of Ictaluridae known from Pigeon Lake: channel catfish, tadpole madtom, brown, yellow and black bullhead. The specimen we captured was definitely a bullhead species, but we were unable to ascertain the key character on the spine necessary for speciation. Among adults, brown bullhead was caught most often (120), followed by yellow bullhead (35) and black bullhead (17).

Tadpole Madtom Fry

One tadpole madtom (81.5 mm) was collected in a night surface sample at beach station T (influenced by Pigeon River) on 2 June. Scott and Crossman (1973) reported an age-length relationship for madtom in a lake in Minnesota that would indicate this fish to be 1-yr old. See ADULT AND JUVENILE FISH - Tadpole Madtom for information on madtoms collected and habitat requirements.

Unknown Pisces

There were three larvae we were unable to identify to family, two were collected from Pigeon Lake and one came from Lake Michigan. The Pigeon Lake specimens were captured at openwater station X (undisturbed Pigeon Lake) during a day tow on 2 June when water temperature was 14.8 C. Both larvae were 6 mm. The remaining identified larvae in the sample were alewife and Pomoxis spp.

One unknown larva, also 6 mm, was taken from a 17 June night 3 m tow at openwater Lake Michigan station E (12 m - s.). Water temperature was only 12.9 C. No other larvae occurred in the sample; however, yellow perch and alewife were common in other tows at station E.

Damaged Larvae

Damaged larvae are those larvae which could not be identified due to physical damage to the specimens. In contrast, unknown larvae (XX) were intact but could not be identified. Larvae were damaged by abrasion with the net and its contents, particularly macrophytes. Although numbers of damaged larvae were generally low, their presence biases abundance estimates for all other species. The degree of bias should be roughly proportional to the fraction of damaged larvae within a sample. Our data suggested that this bias was minimal since (1) damaged larvae numbers and concentrations were low and (2) identifiable

larvae within a sample were generally dominated by one species. Hence, damaged larvae were most probably members of the dominant species found in the sample.

During the early June sampling period damaged larvae were found at Pigeon Lake beach station S (influenced by Lake Michigan), openwater stations X (undisturbed Pigeon Lake) and M (influenced by Lake Michigan), in the intake canal and at Lake Michigan openwater station L (6 m - n.). Low numbers of damaged larvae, 25-93/1000 m^3, were observed at these stations (Figs. 144-145); most were caught at night.

On 17-23 June damaged larvae occurred only at Lake Michigan openwater station D (9 m - s.) at a concentration of 22/1000 m^3 (Fig. 146). In June there were five damaged larvae from Pigeon Lake (4-8 mm), two from Lake Michigan (4-8 mm) and one 7 mm specimen taken in the intake canal (Fig. 147). The low number (8) of damaged larvae collected in June and their low concentrations (less than 100/1000 m^3) should not severely bias interpretations of results for other species.

In July, the month of maximum abundance of larvae and macrophytes (which contributed to damaging larvae), maximum numbers of damaged larvae (143) were recorded. More were captured in Pigeon Lake (68) than in Lake Michigan (54). In addition, 12 were observed in Lake Michigan sled tows and nine were recorded from entrainment samples.

In Pigeon Lake during the 7-10 July sampling period, damaged larvae were found at beach stations S and T and in the intake canal. Concentrations there ranged from 34-230/1000 m^3 (Fig. 148). During 24-28 July damaged larvae were found at beach stations V and S, at the latter in rather high concentrations, 3136/1000 m^3 during the day.

In Lake Michigan, damaged larvae were observed at beach station R (n. discharge) on 7-10 July and stations R and Q (s. discharge) on 25-28 July. The highest concentration, over 1143/1000 m^3 was observed at station Q (Fig. 149). Damaged larvae were also observed at a number of Lake Michigan south transect stations (A - 1.5 m, B - 3 m, E - 12 m, G - 18 m, H - 21 m) at night in concentrations ranging from about 20 to 180/1000 m^3 (Fig. 150). At the Lake Michigan north transect on 13 July, damaged larvae were recorded from stations I (1.5 m), J (3 m), N (9 m) and O (12 m) in low densities, less than 60/1000 m^3 (Fig. 151).

A wide length range of damaged larvae (3-25 mm) were captured during July (Fig. 147). In Pigeon Lake, the most abundant length group was 10 mm, with a range from 5 to 15 mm. In Lake Michigan damaged larvae (probably alewives) were generally smaller than Pigeon Lake specimens with a mean of 7.1 mm; some were 25 mm. Damaged larvae in sled tows from Lake Michigan had a length range similar to that found

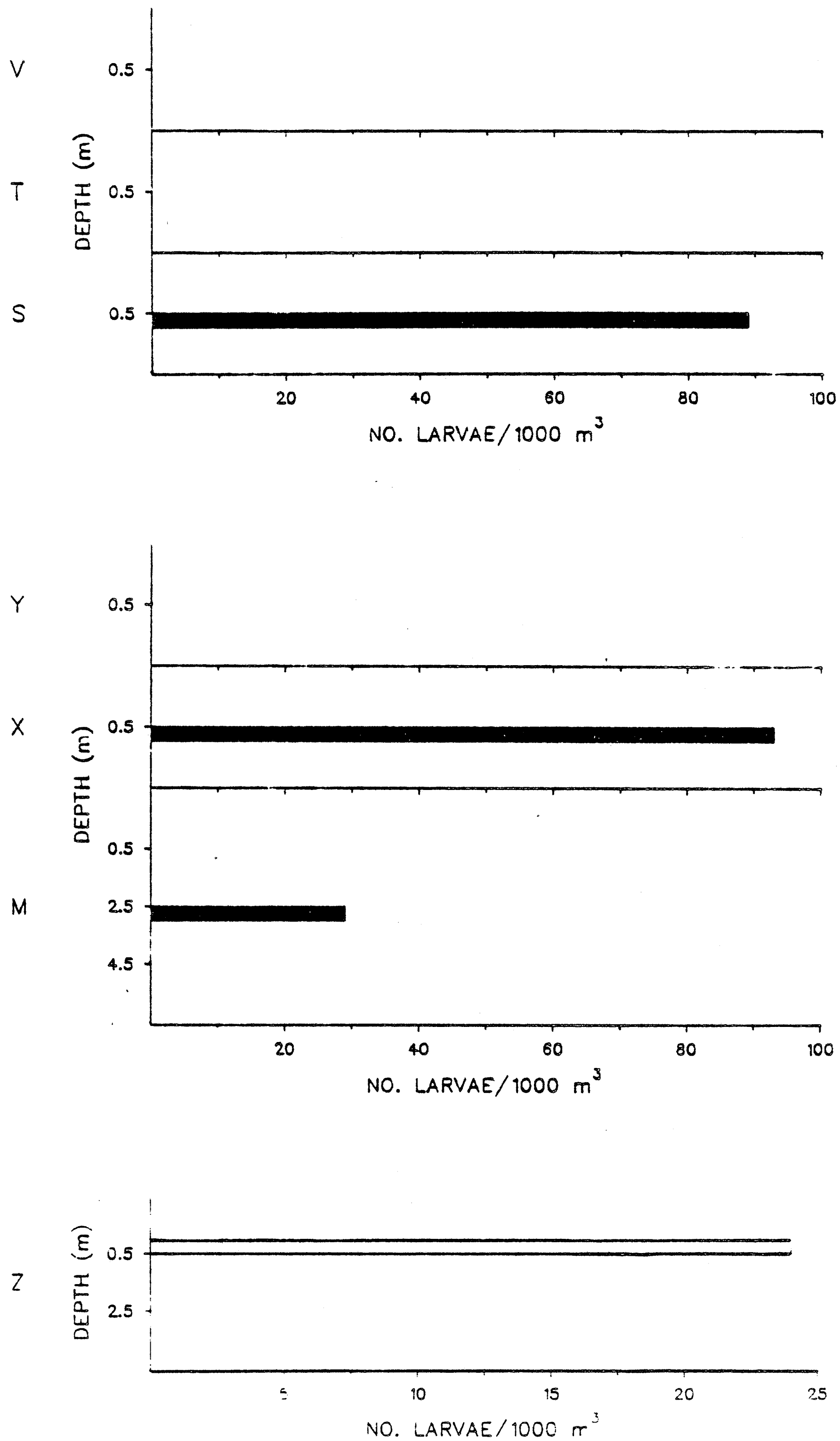


FIG. 144. Number of unidentified damaged larvae per 1000 m^3 for beach, openwater and intake canal stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 31 May - 3 June 1977. □ = Day ■ = Night

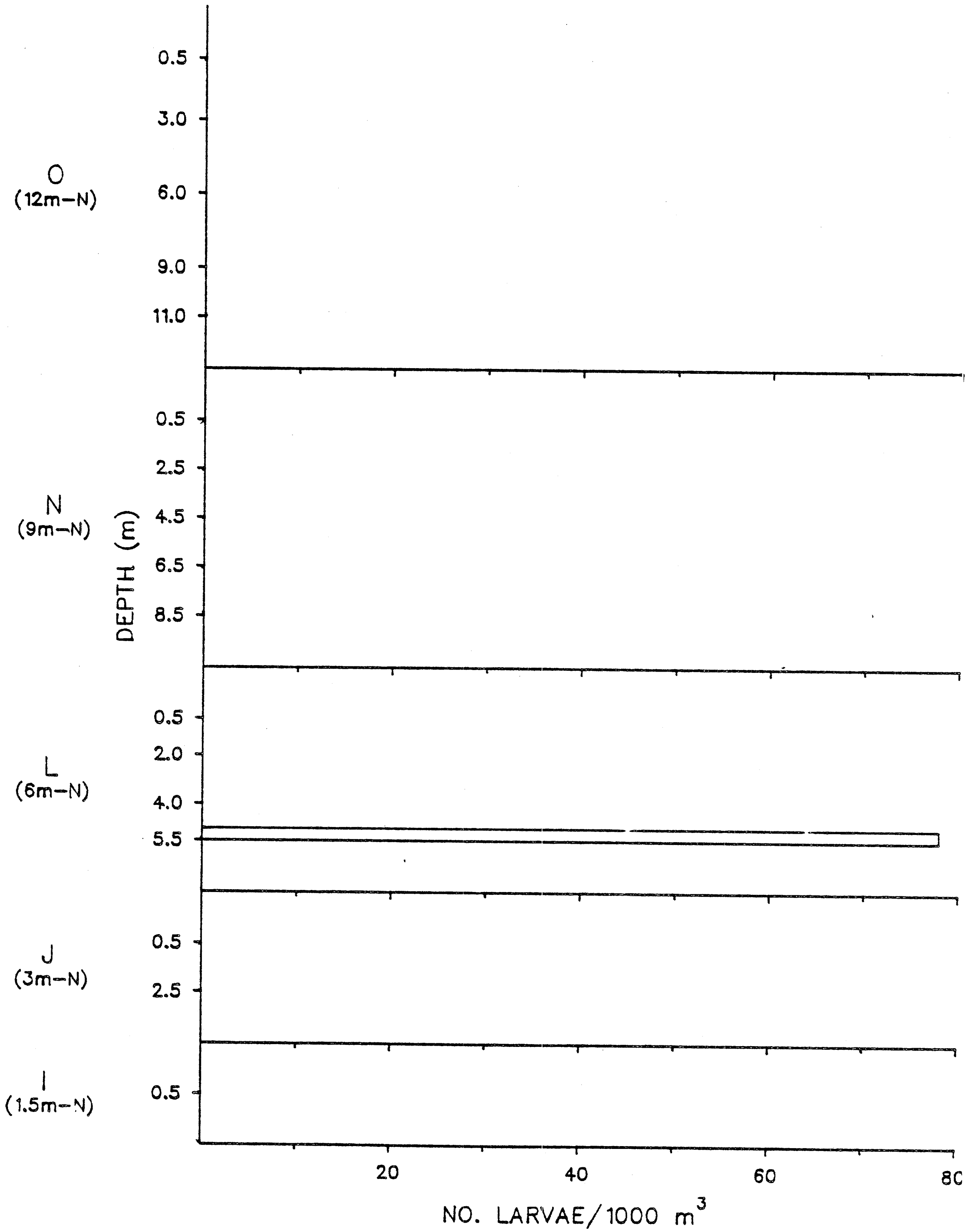


FIG. 145. Number of unidentified damaged larvae per 1000 m^3 for north transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 31 May - 3 June 1977. □ = Day ■ = Night

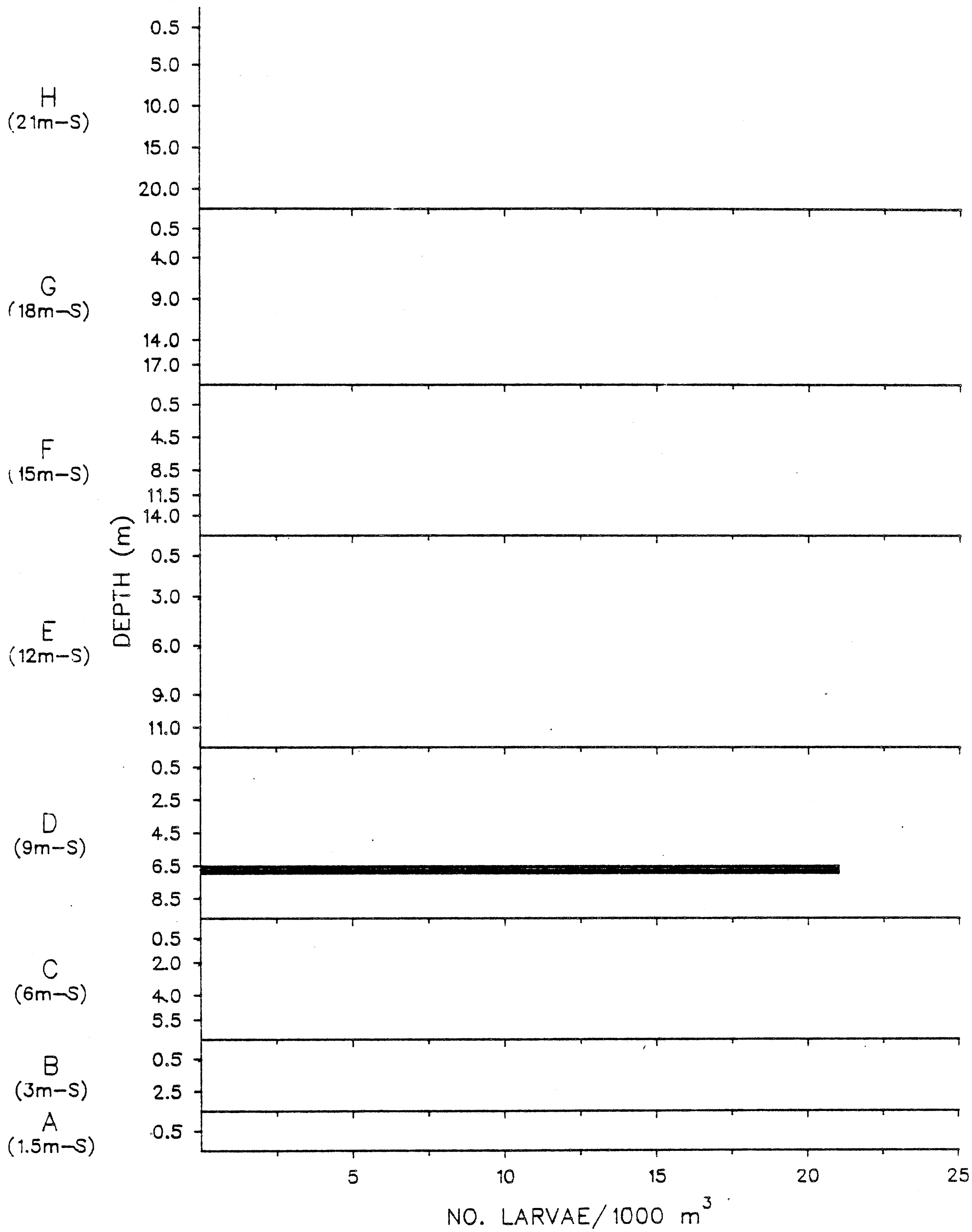


FIG.146. Number of unidentified damaged larvae per 1000 m^3 for south transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 17-23 June 1977. □ = Day ■ = Night

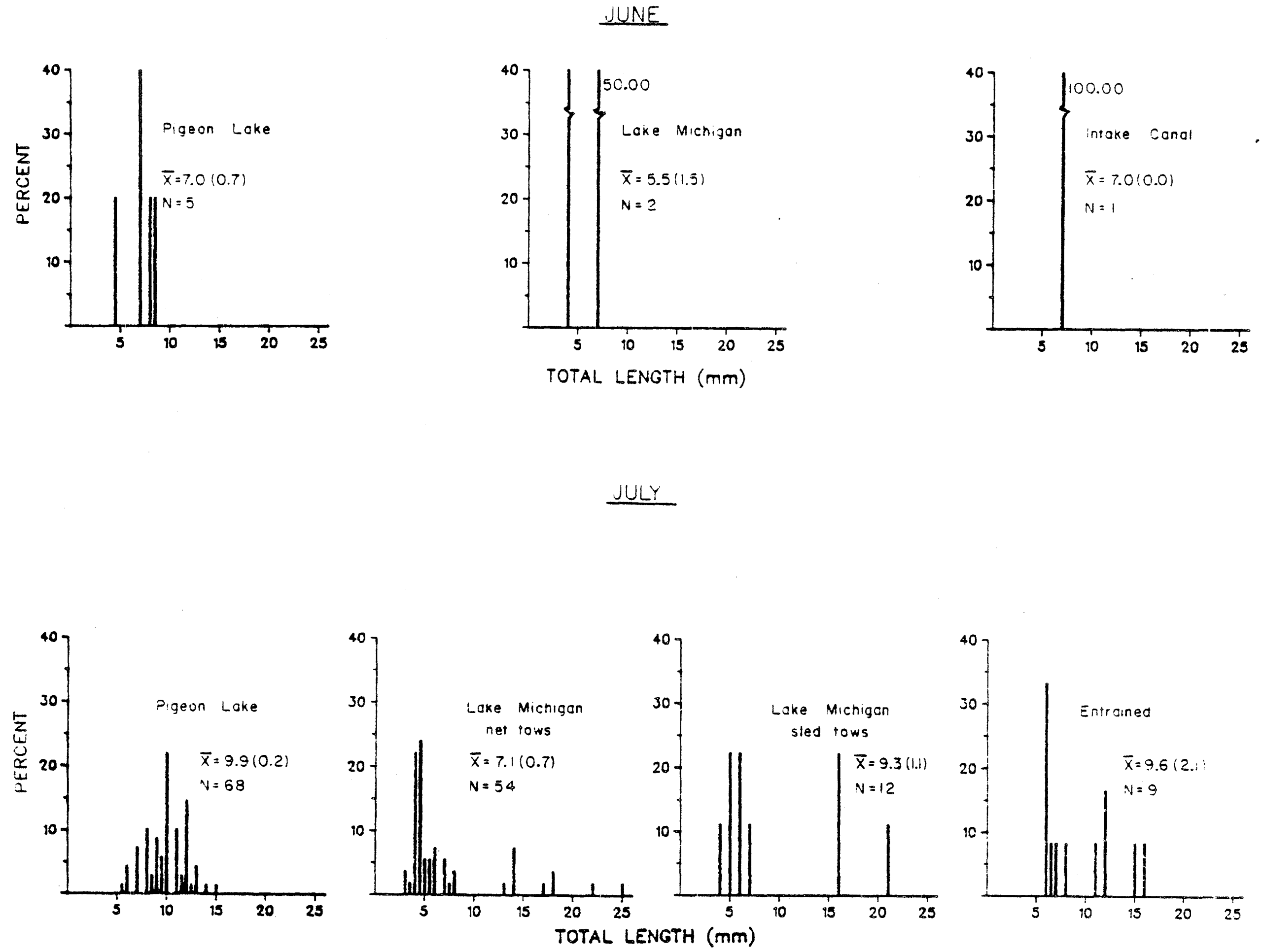


FIG. 147. Length-frequency histogram for unidentified damaged larvae caught at selected pooled stations in Lake Michigan and Pigeon Lake near the J.H. Campbell Plant, 1977. All tows were net tows unless sled tows were specified. ($\bar{X}$=mean, N=total number of larvae used in the comparison, standard error is given in parenthesis.)

for net-caught specimens from both Pigeon Lake and Lake Michigan, 6-16 mm. Damaged larvae constituted a small fraction of the larvae entrained and should not bias entrainment results. Only nine larvae (4-22 mm) were found damaged in entrainment samples.

In August damaged larvae were collected only once at openwater station I_3(1.5 m - n.) (Fig. 152), where the density of larvae was 27/1000 m^3. These larvae were both small, about 5 mm.

Overall, the low numbers and abundance of damaged larvae caught in June and August should have a negligible effect on interpretations of

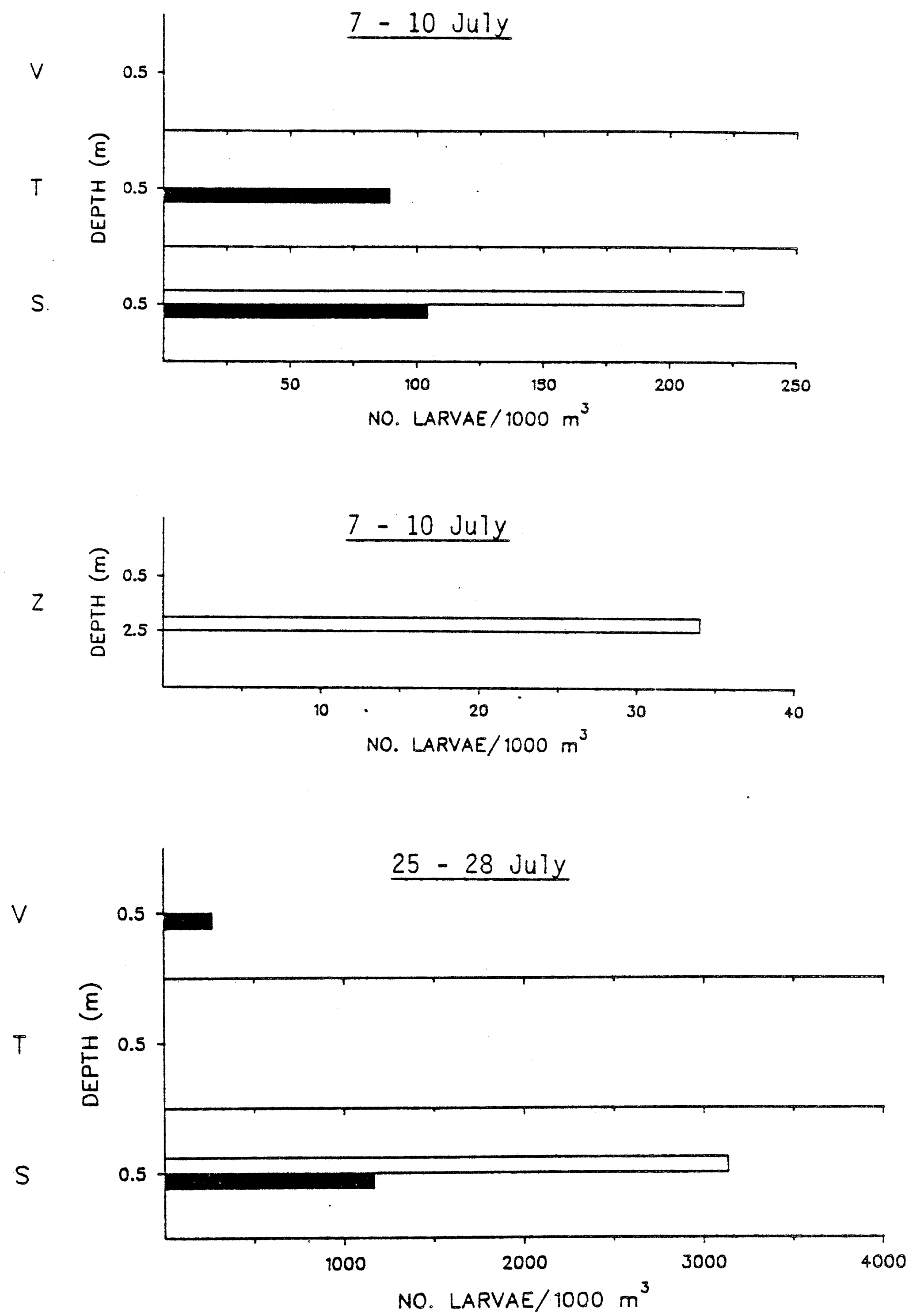


FIG. 148. Number of unidentified damaged larvae per 1000 m^3 at beach stations in Pigeon Lake near the J. H. Campbell Plant, eastern Lake Michigan, 1977. □ = Day ■ = Night

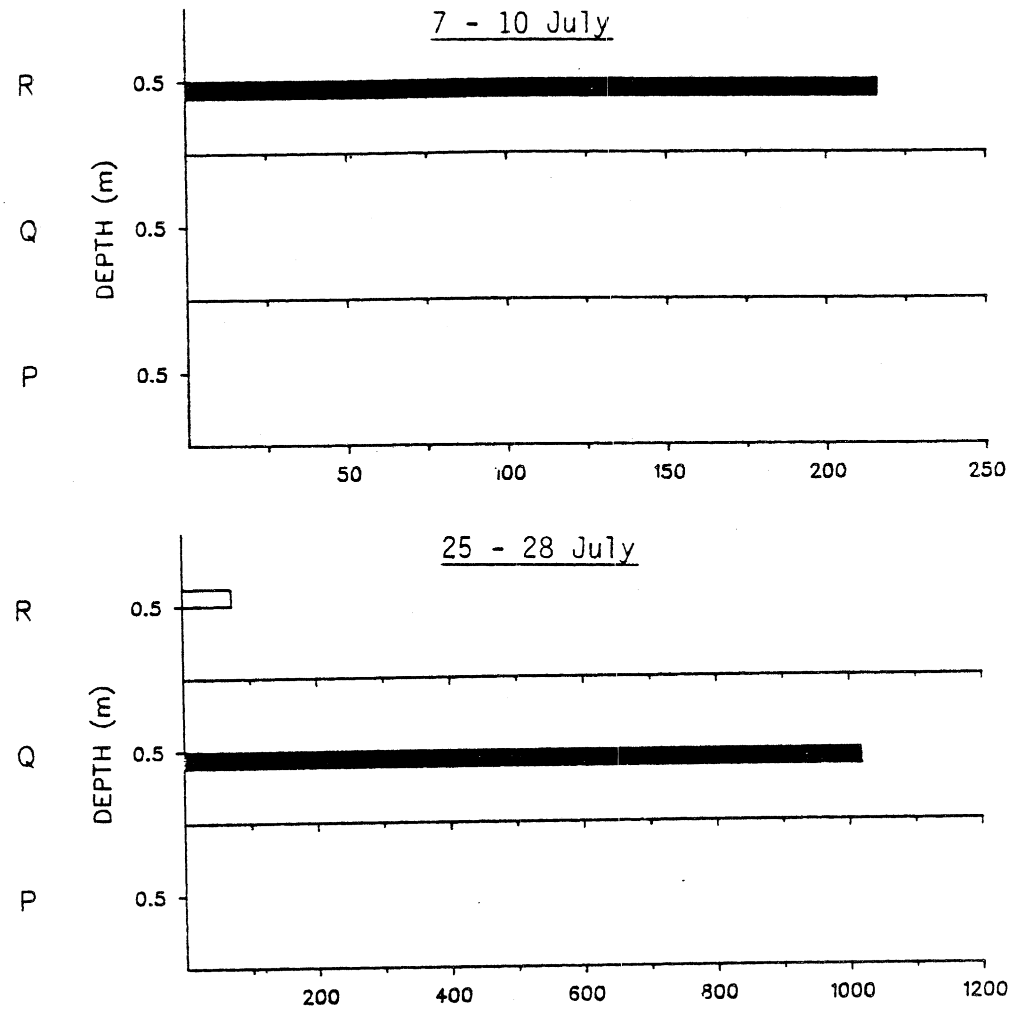


FIG. 149. Number of unidentified damaged larvae per 1000 m^3 for Lake Michigan beach stations near the J. H. Campbell Plant, eastern Lake Michigan, 1977. □ = Day ■ = Night

results for other species. During July abundance of damaged larvae was high, but these larvae were still a small fraction of the observed larvae. Most likely, the damaged larvae in July were alewives.

FISH LARVAE TOTAL LENGTH-BODY DEPTH RELATIONSHIP

Measurements of total length and body depth were made for 245 fish larvae of nine different species (Table 58). It was hoped that at least five larvae of each species could be found for each 5 mm length interval, but limited availability of certain sizes of larvae resulted in gaps in the data (Table 59). For certain species (burbot, carp and trout-perch) length ranges did not cover the entire 25.4 mm (Table 60, Fig. 153A). However, certain calculations were made from the regression

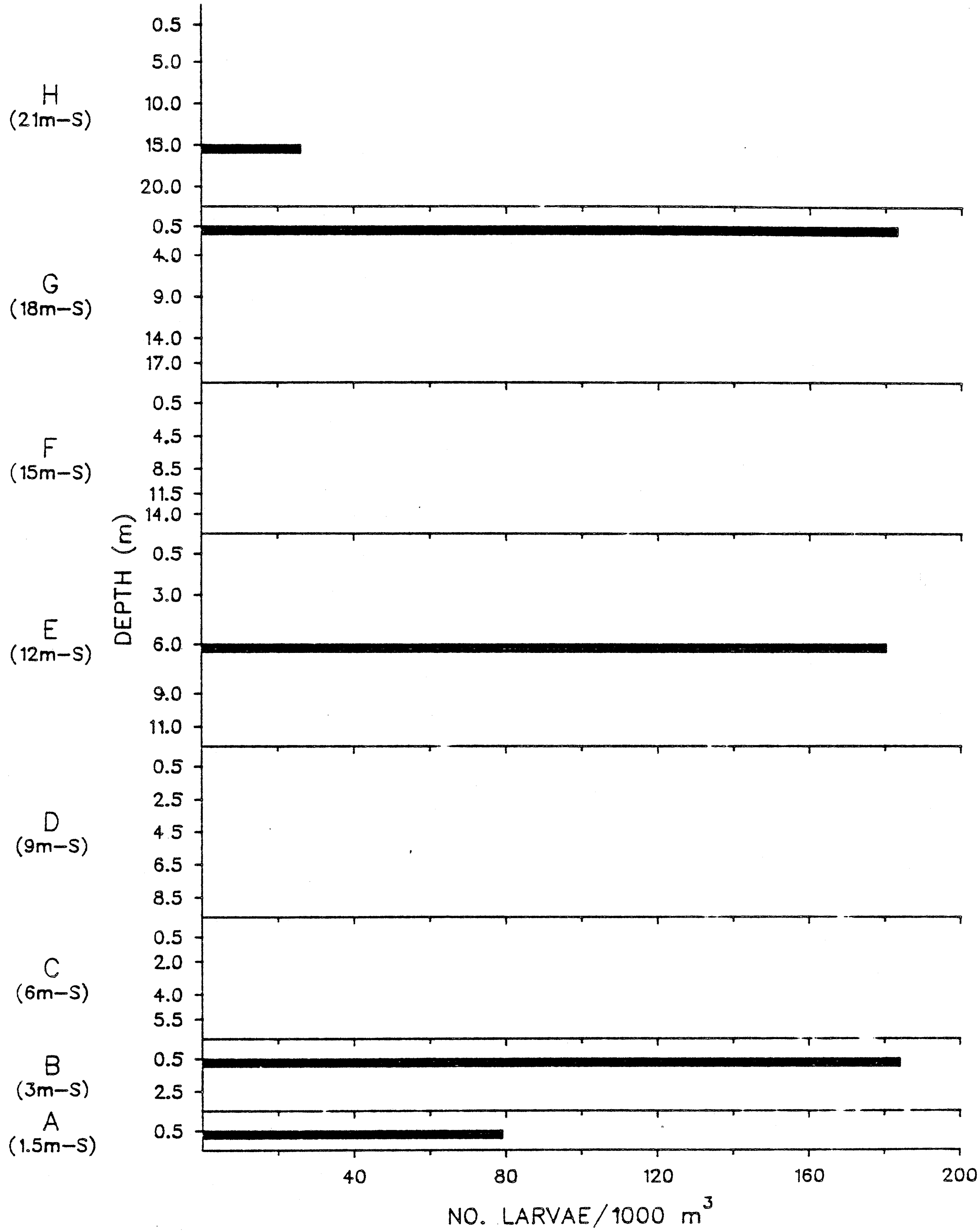


FIG. 150. Number of unidentified damaged larvae per 1000 m^3 for south transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 7-10 July 1977. □ = Day ■ = Night

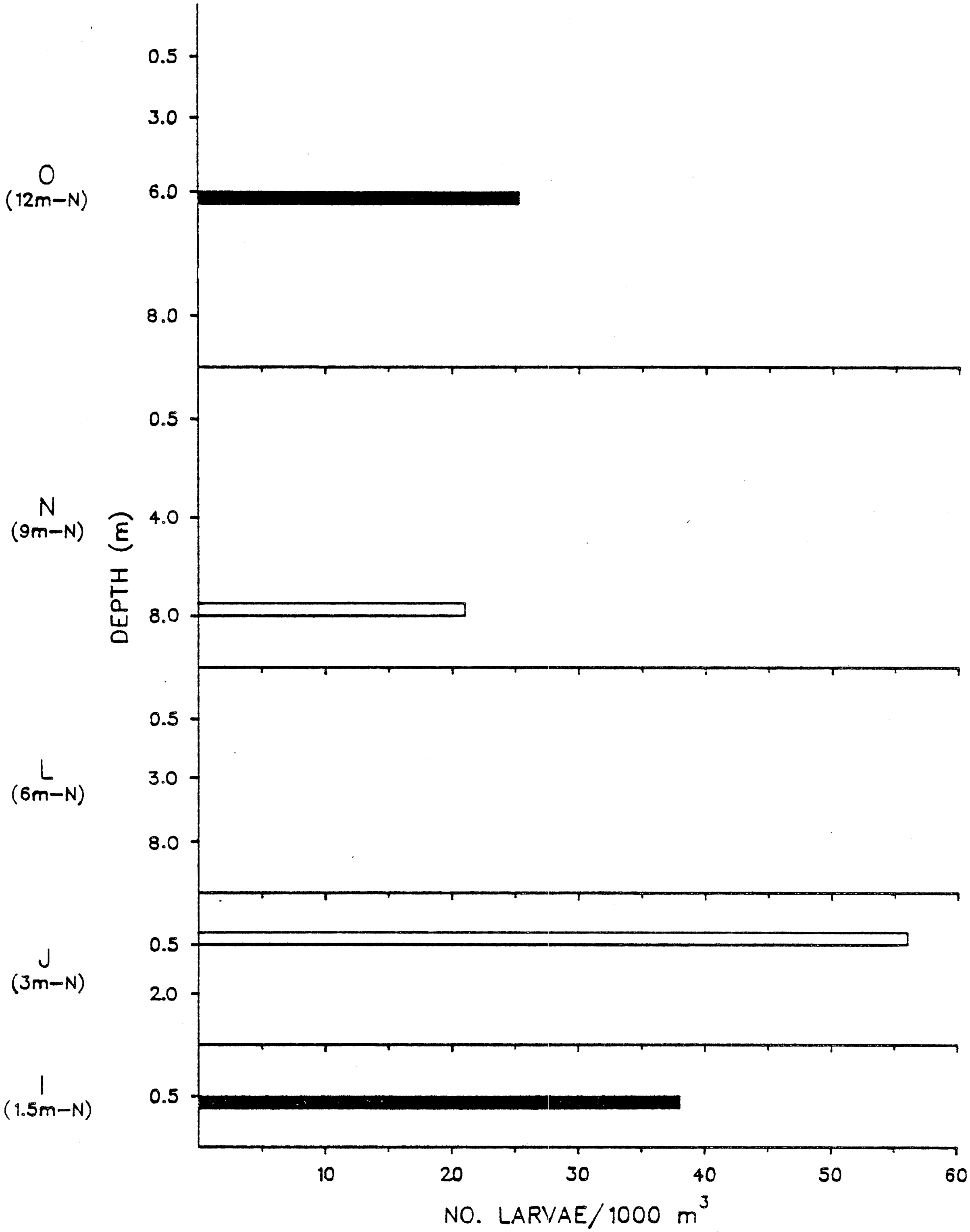


FIG. 151. Number of unidentified damaged larvae per 1000 m^3 for north transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 13 July 1977. □ = Day ■ = Night

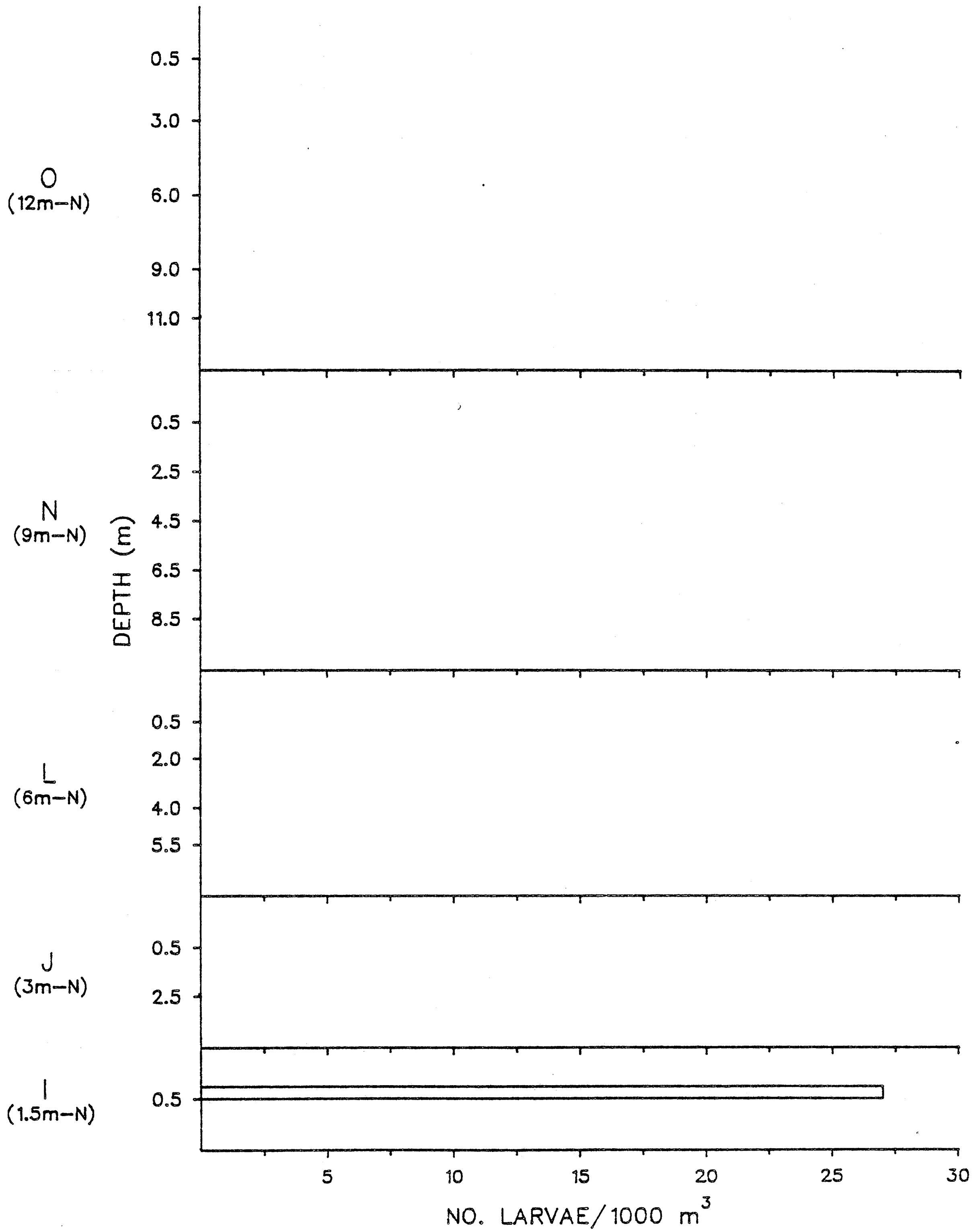


FIG. 152. Number of unidentified damaged larvae per 1000 m^3 for north transect openwater stations in Lake Michigan near the J. H. Campbell Plant, eastern Lake Michigan, 15-19 August 1977. □ = Day ■ = Night

TABLE 58. Total length and body depth statistics of common Lake Michigan larval fishes.

	ALEWIFE	BURBOT	CARP	*COTTUS* SPP.	JOHNNY DARTER	RAINBOW SMELT	SPOTTAIL SHINER	TROUT-PERCH	YELLOW PERCH
Minimum Length (mm)	2.5	4.0	5.0	6.0	3.0	4.0	4.3	4.5	4.8
Maximum Length (mm)	25.0	13.2	13.8	18.0	20.0	25.0	24.9	17.8	22.8
Mean Length (mm)	10.7	6.2	8.5	8.6	9.2	9.9	11.6	9.4	9.6
Minimum Body Depth (mm)	0.3	0.4	0.7	1.0	0.6	0.2	0.4	0.6	0.5
Maximum Body Depth (mm)	3.7	2.1	3.0	4.0	2.8	2.7	4.5	3.0	3.7
Mean Body Depth (mm)	1.1	1.0	1.3	2.1	1.4	0.8	1.7	1.5	1.3

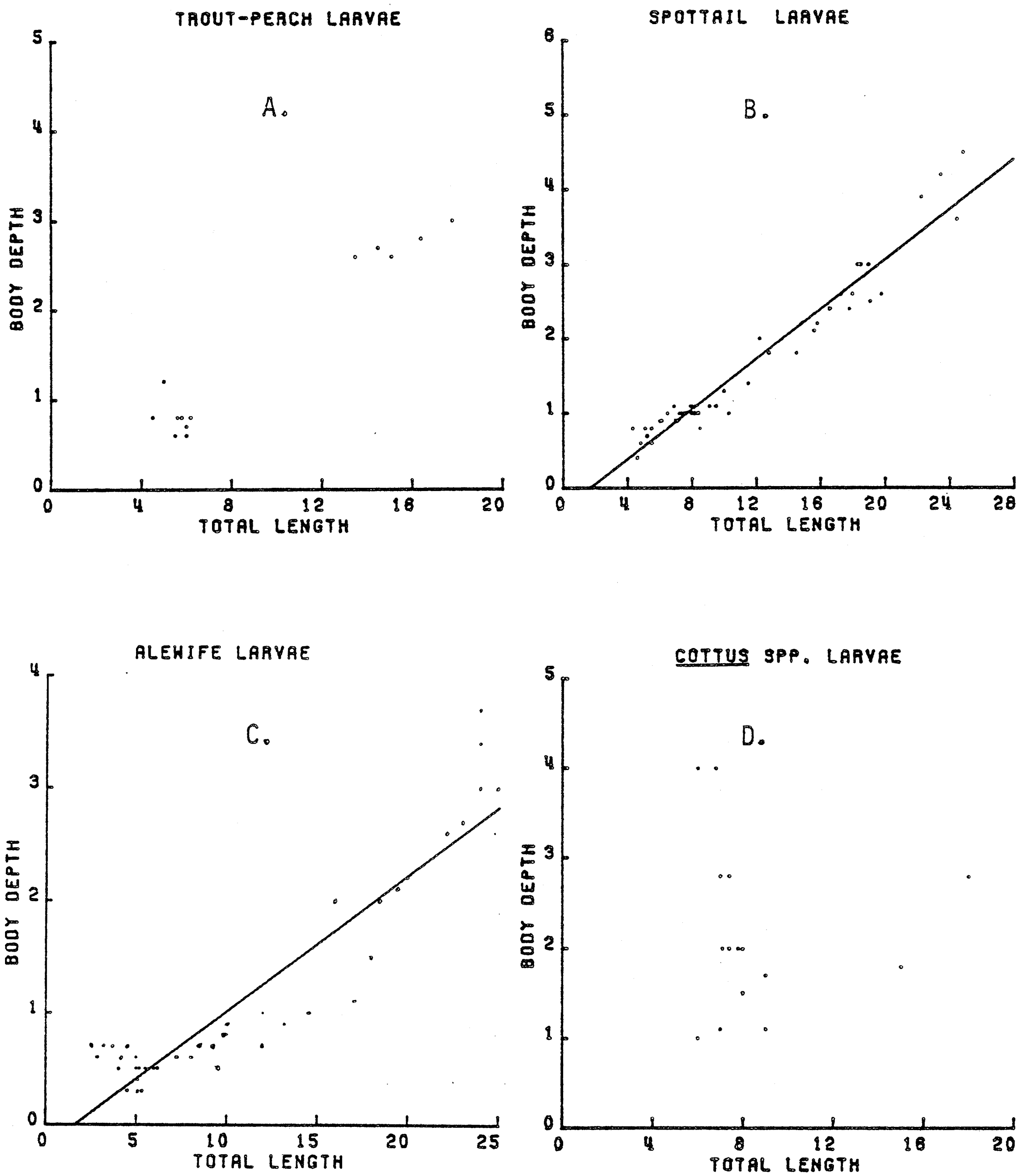


FIG. 153 . Scatter plots representing three types of total length-body depth relationship results: A) insufficient data for meaningful regression; B) and C) linear relationships; D) curvilinear relationship due to yolk sac influence.

TABLE 59. Number of larval fish specimens per 5 mm length interval used in total length-body depth regression equations. Most larvae were from Lake Michigan.

	SPECIES								
Length Interval (mm)	Alewife	Burbot	Carp	Cottus spp.	Johnny Darter	Rainbow Smelt	Spottail Shiner	Trout-Perch	Yellow Perch
0-5.0	11	7	1	-	5	7	3	2	4
5.1-10.0	17	5	11	14	10	11	24	6	21
10.1-15.0	4	1	4	1	5	5	6	2	12
15.1-20.0	6	-	-	1	3	2	12	3	1
20.1-25.0	6	-	-	-	-	4	4	-	3
TOTAL	45	13	16	16	23	29	49	13	41

equations generated by MIDAS for these species (Table 61). Alewife, rainbow smelt, spottail shiner and yellow perch showed a linear relationship between total length and body depth with R^2 values greater than or equal to 0.85 (Table 60, Fig. 153B and C). Cottus spp. and to a lesser extent, johnny darter showed a curvilinear total length-body depth relationship due to yolk-sac influence (Table 60, Fig. 153D).

For alewife, the most abundant larval species entrained at the Cook and Campbell Plants, 45 larvae were measured. The smallest was 2.5 mm in total length with a corresponding body depth of 0.3 mm. Since the smaller larvae of this species (and most other species) tend to be entrained at a far higher rate than larger larvae, (see Fish Larvae and Entrainment Species) it is possible that most newly hatched larvae would pass, head on, through a 0.5 mm screen. However, this does not take into consideration any avoidance ability or behavioral reaction to a screen. The largest alewife larva measured was 25 mm with a body depth of 3.7 mm. Many alewives larger than 25 mm (unlike most other species) were entrained. The regression of body depth on total length was linear with an R^2 value of 0.85 (Fig. 153C).

Rainbow smelt larvae were probably entrained in large numbers during their peak hatching period in May. A linear relationship between total length and body depth ($R^2 = 0.87$) was found for this species. Of the 29 fish measured, the smallest, (newly hatched) was 4.0 mm with a body depth of 0.2 mm. As with alewife, all newly hatched rainbow smelt could potentially pass, head on, through a 0.5 mm mesh screen. The largest rainbow smelt larva measured 25 mm in length and 2.7 mm in depth. Large numbers of fry (>25 mm) of this species were entrained during late summer and fall. These could be excluded by most smaller mesh sizes of intake screens.

The 49 spottail shiner larvae measured showed a linear relationship between total length and body depth with a high (0.95) regression

TABLE 60. Summary of total length-body depth regression analyses for common Lake Michigan larval fishes.

SPECIES	SLOPE	Y-INTERCEPT	R^2	MEAN SQUARE ERROR	N
Alewife	0.12066	-0.19394	0.85	0.12826	45
Burbot	0.17118	-0.40646	0.77	0.06379	13
Carp	0.17639	-0.21584	0.59	0.13218	16
Cottus spp.	-0.00396	2.16529	0.00	0.92085	16
Johnny darter	0.12115	0.32023	0.72	0.16095	23
Rainbow smelt	0.10847	-0.24987	0.87	0.07029	29
Spottail shiner	0.16717	-0.27825	0.95	0.05621	49
Trout-perch	0.19119	-0.25428	0.95	0.05508	13
Yellow perch	0.17260	-0.33124	0.94	0.04708	41

coefficient (Fig. 153B). Minimum length of larvae measured was 4.3 mm, minimum body depth was 0.4 mm. Maximum measurements were 24.9 mm for total length and 4.5 mm for body depth. Spottail shiner were rarely entrained at either the J. H. Campbell or D. C. Cook Plants (Jude et al. 1975, 1979).

Yellow perch were susceptible to entrainment at the Campbell Plant only when they were newly hatched. The 41 larvae measured yielded a linear total length-body depth equation with an R^2 value of 0.94. Minimum length of newly hatched larvae was 4.8 mm with a corresponding body depth of 0.5 mm. Maximum length of perch larvae was 22.8 mm; body depth was 3.7 mm.

Curvilinear total length-body depth relationships were manifested by large body depth values at relatively short total lengths due to the presence of a sizeable yolk sac, this was observed for *Cottus* spp. and johnny darter. As the yolk sac was absorbed, body depth decreased as length increased. After the yolk sac was gone, body depth increased with length as with other species. *Cottus* spp., of which 16 specimens were measured, ranged from 6.0 to 18.0 mm in length and from 1.0 to 4.0 mm in depth (Fig. 153D). Greatest body depth, 4.0 mm, corresponded to lengths of 6.0-7.1 mm. Body depth then fell sharply with yolk sac absorption and increasing length. At a length of 9.1 mm, body depths were reduced to 1.1-1.7 mm. From 9.1 mm on, length and body depth both increased proportionately. More data may indicate a linear relationship after the yolk sac was absorbed.

TABLE 61. Total length in mm at which common Lake Michigan larval fish attained a body depth of 0.5, 1.0 and 2.0 mm. Total length values were obtained from regression equations.

	BODY DEPTH (mm)		
SPECIES	0.5	1.0	2.0
Johnny darter	_*	5.6	13.8
Trout-perch	3.9	6.5	11.8
Carp	4.0	6.9	12.6
Spottail shiner	4.6	7.6	13.6
Yellow perch	4.8	7.7	13.5
Burbot	5.3	8.2	14.1
Alewife	5.7	9.9	18.2
Rainbow smelt	6.9	11.5	20.7

* Not meaningful because total length less than hatching length.

Twenty-three johnny darters were measured with a length range of 3.0-20.0 mm at a body depth range of 0.6-2.8 mm. Much variation in measurements was observed. For example, body depth was as great as 1.8 mm for lengths of around 5 mm while other specimens of comparable length had body depths of 0.7 and 0.9 mm. At lengths of about 7.0 mm, when the yolk sac was absorbed, body depths of 0.7-0.8 mm were recorded. Beyond this length, both total length and body depth increased proportionately to maximum values measured.

Of the species analyzed, alewife and rainbow smelt have to grow well beyond the most frequently entrained, newly hatched size before body depths of 0.5, 1.0 and 2.0 mm were attained (Table 61). Body-depth data would suggest that these two species must reach relatively greater size, compared with other species examined, before they could be excluded by small screen meshes.

The numbers of larvae entrained in 1977 at the J. H. Campbell Plant varied considerably according to species. Calculations of the percentage of alewife, spottail shiner, rainbow smelt and yellow perch that could potentially be excluded by small mesh screens assuming no avoidance are biased for some species because of the small sample size (Table 62). With a large sample size, (2,786 larvae), it was estimated that only 49% of all larval alewives entrained in July 1977 at the Campbell Plant (see Fish Larvae and Entrainment Study -- Alewife) could

TABLE 62. Percentage of common Lake Michigan fish larvae that could be excluded by 0.5, 1.0 and 2.0 mm mesh screens. Percentages calculated from 1977 length frequency entrainment data from the J. H. Campbell Plant. N = number of specimens entrained.

Species	Mesh Size 0.5 mm	1.0 mm	2.0 mm	Month	N
ALEWIFE	48.9	27.8	7.2	July	2786
	97.8	82.9	60.5	August	2084
	100.0	100.0	60.0	September	85
	100.0	100.0	100.0	October	6
All Months Combined	70.4	50.4	30.6		4961
SPOTTAIL SHINER	93.3	20.0	6.7	July	15
	100.0	100.0	72.2	August	18
All Months Combined	96.9	63.6	42.4		33
RAINBOW SMELT	100.0	100.0	100.0	July	2
	100.0	100.0	100.0	August	4
	100.0	100.0	100.0	September	1
All Months Combined	100.0	100.0	100.0		7
YELLOW PERCH	100.0	100.0	100.0	July	1

have been protected from entrainment, even by a 0.5 mm screen. By August, large larvae with a higher potential for survival in nature, had increased in total length and body depth to such an extent that it was likely that nearly 100% exclusion of larval alewives by small mesh screen would be expected. Large numbers of larval alewives could have been entrained in July even if 2.0 mm screens were employed but the magnitude of entrainment would have dropped significantly by August. To have achieved 100% protection from entrainment for alewife in all months, based on body-depth data and lack of behavioral considerations a 0.3 mm mesh screen would be required.

Using the same data and assumptions, a 0.5 mm screen should have provided 90% protection for all spottail shiner, rainbow smelt and yellow perch larvae entrained in July and 100% protection in August, but these conclusions are based on limited data. As with alewife, 2.0 mm mesh screens would provide considerably less protection for these other species.

Estimates of exclusion (Table 62) were made assuming that larvae pass through screens head first, that larvae with body depths equal to mesh size would be excluded and that there was no avoidance or behavioral responses. Tomljanovich et al. (1977) however, found that fish with body depths up to 84% greater than mesh size could pass through the mesh and be entrained depending on approach velocity of intake water. Thus, low intake water velocities will certainly aid in alleviating the entrainment problem. Because of Tomljanovich's findings, the percentage fish larvae excluded by small mesh screens would span a certain range of larval total lengths and not be as clear as this paper presents. A further point not considered here is mortality of retained larval fish due to impingement duration on small mesh screens (Hadderingh 1974, Tomljanovich et al. 1977).

There is a need for more data on the total length-body depth relationship for other species of fish larvae. This presentation is the first attempt to make such correlations for Lake Michigan fishes. Based on the species for which adequate data were gathered however, it appeared that a sound statistical relationship could be established between total length and body depth of larval fish and that this relationship could be useful in predicting the effectiveness of various mesh sizes of intake screens in preventing entrainment of fish larvae.

BENTHOS - LAKE MICHIGAN AND PIGEON LAKE

Lake Michigan - General

Interest in the role of benthos in the ecology of Lake Michigan and the Great Lakes has increased over the last few decades. Although little work has been done on productivity and energetics of the benthos as they relate to other organisms, e.g. fish, in the lakes, much is being published based on the survey approach. Many of the studies operate on the assumption that although the benthos are difficult to study, they are good long-term indicators of the effect of suspected contaminants (Carr and Hiltunen 1965, Howmiller and Beeton 1970). While some benthic forms are mobile (some chironomids, naidids and *Pontoporeia affinis*), most are confined to a small area. Of the mobile forms, only a small percentage actually migrate from the bottom at a given time, except during heavy wave action. Therefore, benthos are valuable in assessing long-term exposure to a contaminant.

Benthic surveys have been published for the Grand Haven and Holland area by Powers and Robertson (1965), Robertson and Alley (1966), Hiltunen (1967), Alley (1968), Alley and Mozley (1975), Consumers Power Company (1975) and the Water Resources Commission (1968). These studies provided baseline data for the examination of benthic macroinvertebrates along the central-eastern shore of Lake Michigan.

Focus of the present sampling effort in Lake Michigan was to survey a large area near the Campbell Plant for the followng reasons: 1) determination of benthic community structure at various depths, and nearshore/offshore abundance (density), 2) estimation of variance inherent in the benthic population in the vicinity of the Campbell Plant and 3) determination of a sample design adequate for surveys in this area of Lake Michigan in relation to the future offshore intake/discharge structures now being built and effects of the associated thermal plume on the benthic community.

Lake Michigan - Community Structure

Total Animal Distribution --

Distribution of total animals in Lake Michigan during the June 1977 sampling period followed the same general pattern in all three regions (see METHODS - BENTHOS for definitions of regions and depth zones). The generalized pattern was one of lowest average total abundance occurring at the 3-6 m depth zone ($2600\text{-}4600/m^2$, Fig. 154), increasing abundances at 9-12 m ($6700\text{-}8500/m^2$), peak abundances at 15 m ($13200\text{-}17900/m^2$) and slightly decreased abundances at 20 and 25 m ($8100\text{-}13400/m^2$). Although each region followed this general pattern, abundances in the 15-25 m

depth zones deviated from this trend the most. The middle region at 15 m, which was offshore from the present discharge, had approximately 4000/m^2 more animals than did either the north or south region. Abundance of animals in the south region was similar at the 20 and 25 m contours when compared with numbers of animals found at 15 m. This was not true in the north and middle region. While abundance of animals was similar in the north region at 25 m and 15 m, abundance of organisms was approximately 4000/m^2 less at 20 m when compared to 15 and 25 m. The number of animals at 20 and 25 m in the middle region was approximately 9000/m^2 less than was found at 15 m.

The middle region was richer in the number of species present when compared to the north and south regions. Over the entire survey area 88 identifiable taxa were found. Of these, 77 were found in the middle region, 70 in the north and 71 in the south (Table 63). The middle region was the richest only at shallow depth zones (3-9 m). The most diverse depth zones were 9 m (57 taxa) and 12 and 15 m (58 taxa). Beyond 9 m, the middle region had consistently fewer taxa (2-8) than either the north or south regions. Neither the north nor south regions had consistently greater or fewer taxa than the other.

Chironomidae Distribution --

Thirty-one taxa of chironomids were identified from Lake Michigan near the Campbell Plant. Distribution of chironomids was similar in all three regions but varied across the depth zones considered (Tables 64-70, Fig. 155). The general pattern was one of similar abundances at 3 m (2600-3400/m^2), 6 m (3000-4600/m^2) and 9 m (3000-4100/m^2). Greatly reduced abundances began at 12 m and extended to 25 m (400-800/m^2).

Specific differences between regions and depth zones for chironomids as well as other major taxonomic groups will be dealt with in the statistical section to follow (see <u>Lake Michigan - Statistical Analysis</u>). In addition chironomids were sorted into two groups arbitrarily called the shallow-zone chironomids (3-9 m) and deep-zone chironomids (12-25 m) based on numerical importance and taxonomic differences. Shallow-zone chironomids were represented by 26 taxa and comprised numerically 43-96% of the total animals present in the 3-9 m zone. Deep-zone chironomids were made up of 20 taxa and comprised numerically 4-9% of the total animals present at 12-25 m. Of the 18 and 16 chironomid taxa collected at 3 and 6 m, respectively, the dominant chironomids were <u>Robackia</u> cfr. <u>demeijerei</u> (360-2000/m^2), <u>Chironomus</u> sp. (960-1400/m^2) and <u>Saetheria</u> cfr. <u>tylus</u> (360-940/m^2). Chironomid taxa occurring in moderate density at 3-6 m were <u>Cryptochironomus</u> sp. 1, <u>Paracladopelma</u> cfr. <u>nereis</u>, <u>Paracladopelma</u> cfr. <u>undine</u> and <u>Cladotanytarsus</u> sp.

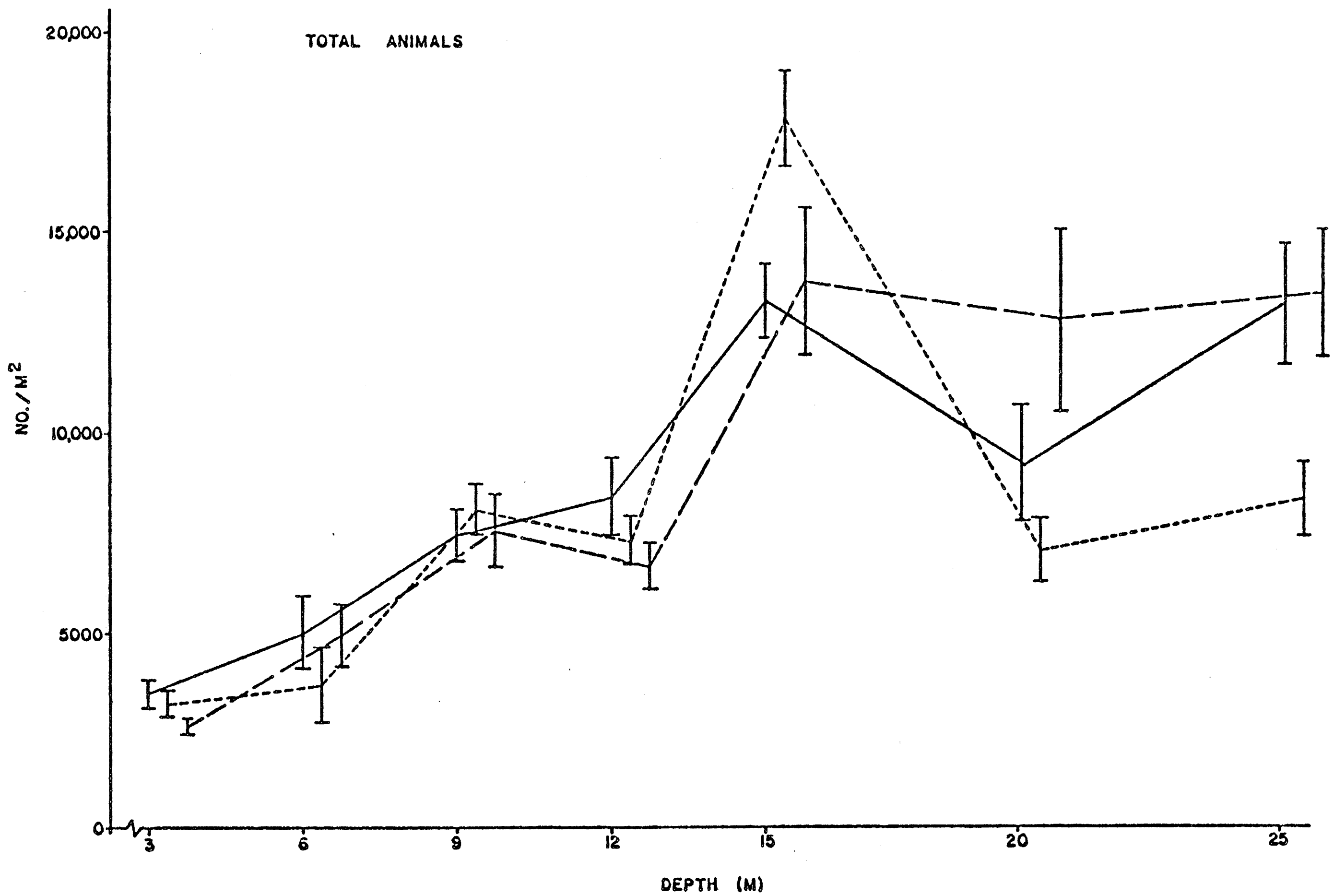


FIG. 154. Abundance of total animals in the north (———), middle (- - - -) and south (— — —) regions over depth near the J. H. Campbell Power Plant in June 1977. Standard error denoted by vertical bar.

TABLE 63. Species list and presence/absence data in each depth zone and region for benthos collected in Lake Michigan near the J.H. Campbell Power Plant in June 1977 (N = north region, M = middle region, S = south region, m = meters, X = presence of a particular taxon).

TAXA	DEPTH ZONE																					REGIONAL OCCURRENCE
	3 m			6 m			9 m			12 m			15 m			20 m			25 m			
	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	
Annelida																						
Oligochaeta																						
Tubificidae																						
Im w/o hc	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	NMS
Im w/hc									X	X			X	X	X	X		X	X	X	X	NMS
Limnodrilus hoffmeisteri					X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	NMS
Limnodrilus spiralis							X	X	X	X	X	X	X		X			X	X		X	NMS
Limnodrilus angustipenis							X	X	X	X	X	X		X	X							NMS
Limnodrilus claparedeianus																		X				S
Limnodrilus profundicola					X	X	X	X		X	X		X	X				X		X		NMS
Potamothrix moldaviensis				X			X	X	X	X	X	X	X	X	X		X	X				NMS
Potamothrix vejdovskyi										X			X	X	X	X		X	X		X	NMS
Peloscolex freyi							X	X	X	X												NMS
Peloscolex superiorensis															X	X		X	X	X	X	NMS
Rhyacodrilus coccineus							X															N
Regional Total/Depth Zone	0	0	0	1	2	1	7	6	5	7	5	4	5	5	6	3	2	7	4	3	3	
Depth Zone Total		0			3			7			7			7			7			5		
Lumbriculidae																						
Stylodrilus heringianus													X	X	X	X	X	X	X	X	X	NMS
Enchytraeidae								X		X		X			X	X	X	X			X	NMS
Naididae																						
Nais elinguis	X	X		X	X	X	X															NMS
Nais variabilis	X	X	X	X	X	X	X	X	X		X	X										NMS
Nais communis															X		X					MS

TABLE 63. (continued).

TAXA	DEPTH ZONE																						
	3 m			6 m			9 m			12 m			15 m			20 m			25 m			REGIONAL OCCURRENCE
	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	
<u>Nais bretscheri</u>	X	X		X	X		X	X	X	X	X	X	X		X							NMS
<u>Nais simplex</u>					X	X						X										MS
<u>Stylaria lacustris</u>	X	X		X	X	X	X	X	X	X	X	X	X	X								NMS
<u>Chaetogaster diaphanus</u>		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				NMS
<u>Piguetiella michiganensis</u>		X		X	X	X	X	X	X	X	X	X	X	X	X	X		X		X		NMS
<u>Uncinais uncinata</u>		X		X	X	X	X	X	X	X	X	X	X	X	X							NMS
<u>Paranais simplex</u>			X	X	X	X	X	X	X		X	X		X	X	X	X	X			X	NMS
<u>Paranais litoralis</u>					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	NMS
<u>Vejdovskyella intermedia</u>					X	X	X	X			X	X	X	X	X			X	X		X	NMS
<u>Dero digitata</u>				X			X				X			X								NM
<u>Pristina foreli</u>												X			X							S
<u>Amphichaeta leydigii</u>							X						X									N
<u>Arcteonais lomondi</u>													X	X								NM
Regional Total/Depth Zone	4	7	3	9	11	10	12	9	8	6	10	11	9	9	9	4	4	5	2	2	3	
Depth Zone Total		8			11			12			12			13			6			4		
Hirudinea																						
Glossiphoniidae																						
<u>Helobdella stagnalis</u>										X		X				X		X	X			NS
Other Hirudinae										X		X	X	X	X	X	X	X	X	X		NMS
Malacostraca																						
Amphipoda																						
Haustoriidae																						
<u>Pontoporeia affinis</u>		X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	NMS
Mysidacea																						
Mysidae																						
<u>Mysis relicta</u>																					X	S

TABLE 63. (continued).

TAXA	DEPTH ZONE																					
	3 m			6 m			9 m			12 m			15 m			20 m			25 m			REGIONAL OCCURRENCE
	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	
Mollusca																						
Pelecypoda																						
Sphaeriidae																						
Sphaerium striatinum							X	X		X	X		X	X		X	X	X	X	X	X	NMS
Sphaerium nitidum																X	X	X	X		X	NMS
Sphaerium transversum														X	X		X					MS
Pisidium fallax								X	X	X	X	X	X	X	X	X	X	X	X	X	X	NMS
Pisidium casertanum							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	NMS
Pisidium nitidum							X	X		X	X	X	X	X	X	X	X	X	X	X	X	NMS
Pisidium henslowanum										X		X	X	X	X	X	X	X	X	X	X	NMS
Pisidium variabile							X			X	X	X	X	X	X	X	X	X	X	X	X	NMS
Pisidium ferrugineum										X						X	X	X	X		X	NMS
Pisidium subtruncatum										X			X	X	X				X	X	X	NMS
Pisidum nitidum f. *pauperculum*									X	X	X	X	X	X	X	X	X	X		X	X	NMS
Pisidium conventus									X	X		X	X	X	X	X	X	X	X	X	X	NMS
Pisidium compressum								X		X			X						X			NM
Pisidium milium											X					X			X			NM
Pisidium walkeri													X									N
Pisidium idahoense						X																S
Pisidium lilljeborgi															X	X		X	X	X	X	NMS
Pisidium adamsi								X														M
Pisidium spp.				X			X			X	X	X	X	X	X	X	X	X	X	X	X	NMS
Regional Total/Depth Zone	0	0	0	0	0	1	4	6	4	11	7	7	11	10	10	12	11	11	13	10	12	
Depth Zone Total		0			1			9			12			13			13			14		

TABLE 63. (continued).

TAXA	DEPTH ZONE																					
	3 m			6 m			9 m			12 m			15 m			20 m			25 m			REGIONAL OCCURRENCE
	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	
Gastropoda																						
Valvatidae																						
Valvata sincera							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	NMS
Hydrobiidae																						
Amnicola sp.							X		X	X	X	X	X	X	X	X		X				NMS
Lymnaeidae																						
Lymnaea sp.																				X		M
Regional Total/Depth Zone	0	0	0	0	0	0	2	1	2	2	2	2	2	2	2	2	1	2	1	2	1	
Depth Zone Total		0			0			2			2			2			2			2		
Turbellaria							X	X		X		X										NMS
Hydracarina				X	X	X		X	X		X		X		X	X						NMS
Coelenterata																						
Hydrazoa																						
Hydridae																						
Hydra sp.				X	X		X					X	X		X	X	X	X	X	X		NMS
Insecta																						
Trichoptera																						
Molannidae																						
Molanna sp.														X								M

TABLE 63. (continued).

TAXA	DEPTH ZONE																					
	3 m			6 m			9 m			12 m			15 m			20 m			25 m			REGIONAL OCCURRENCE
	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	
Diptera																						
Chironomidae																						
Chironomus sp.	X	X	X	X	X	X	X	X	X			X	X									NMS
Chironomus fluviatilis-gr.		X																				M
Cryptochironomus sp. 1	X	X	X	X	X						X											NMS
Cryptochironomus sp. 2		X	X		X	X	X	X	X	X	X	X	X	X				X			X	NMS
Cryptochironomus sp. 3	X	X	X	X	X	X	X	X														NMS
Cryptochironomus cfr. rolli		X																				M
Robackia cfr. demeijerei	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X				NMS
Saetheria cfr. tylus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						NMS
Paracladopelma cfr. nereis	X	X	X	X	X	X	X	X														NMS
Paracladopelma cfr. undine	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			NMS
Paracladopelma cfr. winnelli												X	X	X	X	X	X	X	X	X	X	NMS
Psectrocladius sp.	X	X	X	X	X	X	X	X			X				X							NMS
Cladotanytarsus sp.	X	X		X	X	X	X	X	X	X	X	X	X		X			X				NMS
Parachironomus cfr. abortivus		X																				M
Polypedilum cfr. scalaenum			X	X	X	X	X	X	X	X	X	X	X	X	X		X	X			X	NMS
Polypedilum cfr. halterale			X	X				X			X											NMS
Polypedilum fallax-gr.							X			X		X	X	X	X	X	X	X	X	X	X	NMS
Polypedilum sp. 2										X			X									N
Procladius sp.							X		X	X			X	X	X	X		X	X		X	NMS
Monodiamesa cfr. tuberculata							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	NMS
Heterotrissocladius cfr. changi																X			X		X	NS

TABLE 63. (continued).

TAXA	DEPTH ZONE																					
	3 m			6 m			9 m			12 m			15 m			20 m			25 m			REGIONAL OCCURRENCE
	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	
Heterotrissocladius cfr. oliveri																X			X		X	NS
Micropsectra sp.																					X	S
Tanytarsus sp.									X													S
Nanocladius sp.					X			X														M
Paratendipes sp.								X														M
Cladopelma sp.						X	X	X														NMS
Cricotopus (I) sylvestris-gr.		X		X		X																NMS
Orthocladiini sp. 1	X	X			X	X	X	X	X	X		X		X								NMS
Orthocladiini sp. 2								X														M
Orthocladiini sp. 3	X							X	X	X	X	X										NMS
Regional Total/Depth Zone	11	15	11	12	13	13	15	18	12	12	10	13	13	11	11	9	7	10	7	4	9	
Depth Zone Total		18			16			21			17			15			12			10		
Grand Regional Total/Depth Zone	17	25	15	25	29	28	44	45	34	44	37	45	48	42	46	38	30	32	33	26	33	
Grand Depth Zone Total		29			35			57			58			58			48			43		

TABLE 64. Abundance of the most numerous taxa found near the J. H. Campbell Power Plant at 3m in June 1977 ($\bar{X}$ = mean, S.E. = standard error).

	Depth Zone: 3 meters											
	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total Chironomidae	3357.24	345.32		2999.70	310.75		2593.68	201.76		2983.54	220.57	
Chironomus sp.	418.14	180.78	12.45	381.78	137.61	12.73	139.38	56.45	5.37	313.10	87.49	10.49
Robackia cfr. *demeijerei*	2017.98	268.75	60.11	1315.02	203.02	43.84	1466.52	170.64	56.54	1599.84	213.60	53.62
Cryptochironomus sp. 1	242.40	57.84	7.22	212.10	90.45	7.07	260.58	54.99	10.05	238.36	14.14	7.99
Cryptochironomus sp. 2				18.18	12.93	0.61	30.30	13.55	1.17	16.16	8.80	0.54
Cryptochironomus sp. 3	18.18	12.93	0.54	36.36	13.40	1.21	109.08	15.12	4.21	54.54	27.77	1.83
Saetheria cfr. *tylus*	369.66	47.33	11.01	472.68	68.68	15.76	363.60	61.93	14.02	401.98	35.39	13.47
Paracladopelma cfr. *nereis*	115.14	48.18	3.43	115.14	26.26	3.84	121.20	22.13	4.67	117.16	2.02	3.93
Paracladopelma cfr. *undine*	60.60	25.55	1.81	78.78	23.99	2.63	30.30	16.29	1.17	56.56	14.14	1.90
Paracladopelma cfr. *winnelli*												
Orthocladiini sp. 1	12.12	8.08	0.36	6.06	6.06	0.20				6.06	3.50	0.20
Psectrocladius sp.	18.18	9.26	0.54	84.84	65.89	2.83	6.06	6.06	0.23	36.36	24.49	1.22
Cladotanytarsus sp.	6.06	6.06	0.18	18.18	18.18	0.61				8.08	5.34	0.27
Polypedilum cfr. *scalaenum*												
Polypedilum fallax-gr.												
Monodiamesa cfr. *tuberculata*												
Procladius sp.												
Heterotrissocladius cfr. *changi*												
Heterotrissocladius cfr. *oliveri*												
Others	12.12		0.36	54.54		1.82	36.36		1.40	34.34		1.15

TABLE 64. (continued).

Depth Zone: 3 meters

	North Region			Middle Region			South Region			Total		
	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%
Total Naididae	103.02	31.36		175.74	56.74		24.24	13.40		101.00	43.75	
Nais elinguis	72.72	21.76	70.59	90.90	30.30	51.72				54.54	27.77	54.00
Stylaria lacustris	6.06	6.06	5.88							2.02	2.02	2.00
Nais variabilis	18.18	18.18	17.65	24.24	9.90	13.79	12.12	8.08	50.00	18.18	3.50	18.00
Chaetogaster diaphanus				24.24	24.24	13.79	6.06	6.06	25.00	10.10	7.28	10.00
Piguetiella michiganensis				6.06	6.06	3.45				2.02	2.02	2.00
Uncinais uncinata				24.24	18.51	13.79				8.08	8.08	8.00
Paranais simplex							6.06	6.06	25.00	2.02	2.02	2.00
Paranais litoralis												
Vejdovskyella intermedia												
Nais bretscheri	6.06	6.06	5.88	6.06	6.06	3.45				4.04	2.02	4.00
Others												
Total Tubificidae	6.06	6.06								2.02	2.02	
im w/o hc	6.06	6.06	100.00							2.02	2.02	100.00
im w/ hc												
Limnodrilus hoffmeisteri												
Limnodrilus angustipenis												
Limnodrilus spiralis												
Limnodrilus profundicola												
Limnodrilus claparedianus												
Potamothrix moldaviensis												
Potamothrix vejdovskyi												
Peloscolex freyi												
Peloscolex superiorensis												
Stylodrilus heringianus												
Enchytraeidae												

TABLE 64. (continued).

Depth Zone: 3 meters

	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total Pelecypoda												
Total *Sphaerium*												
S. nitidum												
S. striatinum												
S. transversum												
Total Pisidium												
P. fallax												
P. casertanum												
P. nitidum												
P. henslowanum												
P. variabile												
P. ferrugineum												
P. subtruncatum												
P. nitidum f. *pauperculum*												
P. conventus												
P. compressum												
P. milium												
P. walkeri												
P. idahoense												
P. lilljeborgi												
P. adamsi												
P. spp.												

TABLE 64. (continued).

Depth Zone: 3 meters

	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total *Pontoporeia affinis*				12.12	8.08					4.04	4.04	
P. affinis < 3 mm				12.12	8.08	100.00				4.04	4.04	100.00
P. affinis 3-5 mm												
P. affinis 5-7 mm												
P. affinis > 7 mm												
Total Gastropoda												
Valvata sincera												
Amnicola sp.												
Lymnaea sp.												
Total Hirudinea												
Helobdella stagnalis												
Other Hirudinea												
Total Animals	3466.32	354.26		3199.68	334.35		2617.92	198.50		3094.64	250.78	

TABLE 65. Abundance of the most numerous taxa found near the J.H. Campbell Plant at 6 m in June 1977 ($\bar{x}$ = mean, S.E. = standard error).

Depth Zone: 6 meters

	North Region			Middle Region			South Region			Total		
	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%
Total Chironomidae	4551.06	779.60		2993.64	732.30		3775.38	500.13		3773.36	449.59	
Chironomus sp.	1387.74	603.87	30.49	957.48	513.24	31.98	1205.94	282.14	31.94	1183.72	124.70	31.37
Robackia cfr. demeijerei	1939.20	435.87	42.61	363.60	130.60	12.15	830.22	236.96	21.99	1044.34	467.27	27.68
Cryptochironomus sp. 1	78.78	23.99	1.73	12.12	8.08	0.40				30.30	24.49	0.80
Cryptochironomus sp. 2	6.06	6.06	0.13	48.48	15.12	1.62	84.84	20.60	2.25	46.46	22.76	1.23
Cryptochironomus sp. 3	36.36	16.16	0.80	24.24	18.51	0.81	48.48	25.23	1.28	36.36	7.00	0.96
Saetheria cfr. tylus	769.62	100.62	16.91	939.30	127.20	31.38	436.32	85.61	11.56	715.08	147.74	18.95
Paracladopelma cfr. nereis	48.48	19.79	1.07	48.48	15.12	1.62	230.28	60.47	6.10	109.08	60.60	2.89
Paracladopelma cfr. undine	145.44	54.35	3.20	254.52	51.74	8.50	181.80	41.40	4.82	193.92	32.07	5.14
Paracladopelma cfr. winnelli												
Orthocladiini sp. 1				12.12	8.08	0.40	66.66	35.51	1.77	26.26	20.50	0.70
Psectrocladius sp.	24.24	13.40	0.53	84.84	42.56	2.83	36.36	13.40	0.96	48.48	18.51	1.28
Cladotanytarsus sp.	36.36	20.60	0.80	133.32	44.99	4.45	466.62	154.65	12.36	212.10	130.30	5.62
Polypedilum cfr. scalaenum	18.18	12.93	0.40	42.42	12.93	1.42	133.32	35.91	3.53	64.64	35.05	1.71
Polypedilum fallax-gr.												
Monodiamesa cfr. tuberculata												
Procladius sp.												
Heterotrissocladius cfr. changi												
Heterotrissocladius cfr. oliveri												
Others	18.18		0.40	18.18		0.61	18.18		0.48	18.18		0.48

TABLE 65. (continued).

Depth Zone: 6 meters

	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total Naididae	454.50	152.04		569.64	248.58		1084.74	362.19		702.96	193.76	
Nais elinguis	84.84	30.23	18.67	24.24	13.40	4.26	24.24	18.51	2.23	44.44	20.20	6.32
Stylaria lacustris	12.12	8.08	2.67	36.36	25.87	6.38	18.18	12.93	1.68	22.22	7.28	3.16
Nais variabilis	72.72	32.32	16.00	42.42	25.63	7.45	90.90	18.62	8.38	68.68	14.14	9.77
Chaetogaster diaphanus	109.08	41.20	24.00	248.46	149.11	43.62	472.68	281.03	43.58	276.74	105.91	39.37
Piguetiella michiganensis	103.02	52.71	22.67	54.54	30.57	9.57	212.10	86.29	19.55	123.22	46.59	17.53
Uncinais uncinata	30.30	18.62	6.67	109.08	38.11	19.15	199.98	68.23	18.44	113.12	49.02	16.09
Paranais simplex	18.18	12.93	4.00	12.12	8.08	2.13	12.12	8.08	1.12	14.14	2.02	2.01
Paranais litoralis				6.06	6.06	1.06	24.24	16.16	2.23	10.10	7.28	1.44
Vejdovskyella intermedia				6.06	6.06	1.06	18.18	12.93	1.68	8.08	5.34	1.15
Nais bretscheri	12.12	8.08	2.67	24.24	18.51	4.26				12.12	7.00	1.72
Others	12.12	12.12	2.67	6.06	6.06	1.06	12.12	12.12	1.12	10.10		1.44
Total Tubificidae	12.12	12.12		36.36	18.51		36.36	20.60		28.28	8.08	
im w/o hc	6.06	6.06	50.00	12.12	8.08	33.33	30.30	18.62	83.33	16.16	7.28	57.14
im w/ hc												
Limnodrilus hoffmeisteri				18.18	12.93	50.00				6.06	6.06	21.43
Limnodrilus angustipenis												
Limnodrilus spiralis												
Limnodrilus profundicola				6.06	6.06	16.67	6.06	6.06	16.67	4.04	2.02	14.29
Limnodrilus claparedianus												
Potamothrix moldaviensis	6.06	6.06	50.00							2.02	2.02	7.14
Potamothrix vejdovskyi												
Peloscolex freyi												
Peloscolex superiorensis												
Stylodrilus heringianus												
Enchytraeidae												

TABLE 65. (continued).

Depth Zone: 6 meters

	North Region			Middle Region			South Region			Total		
	$\overline{X}$	S.E.	%	$\overline{X}$	S.E.	%	$\overline{X}$	S.E.	%	$\overline{X}$	S.E.	%
Total Pelecypoda	6.06	6.06					6.06	6.06		4.04	2.02	
Total *Sphaerium*												
S. nitidum												
S. striatinum												
S. transversum												
Total *Pisidium*	6.06	6.06					6.06	6.06		4.04	2.02	
P. fallax												
P. casertanum												
P. nitidum												
P. henslowanum												
P. variabile												
P. ferrugineum												
P. subtruncatum												
P. nitidum f. *pauperculum*												
P. conventus												
P. compressum												
P. milium												
P. walkeri												
P. idahoense												
P. lilljeborgi							6.06	6.06		2.02	2.02	50.00
P. adamsi												
P. spp.	6.06		100.00							2.02		50.00

TABLE 65 . (continued).

Depth Zone: 6 meters

	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total *Pontoporeia affinis*				78.78	27.18		36.36	13.40		38.38	22.76	
P. affinis < 3 mm				72.72	25.23	92.31	36.36	13.40	100.00	36.36	20.99	94.74
P. affinis 3-5 mm												
P. affinis 5-7 mm				6.06	6.06	7.69				2.02	2.02	5.26
P. affinis > 7 mm												
Total Gastropoda												
Valvata sincera												
Amnicola sp.												
Lymnaea sp.												
Total Hirudinea												
Helobdella stagnalis												
Other Hirudinea												
Total Animals	5041.92	933.83		3690.54	967.55		4944.96	841.65		4559.14	435.20	

TABLE 66. Abundance of the most numerous taxa found near the J. H. Campbell Plant at 9 m in June 1977 ($\bar{x}$ = mean, S.E. = standard error).

Depth Zone: 9 meters

	North Region			Middle Region			South Region			Total		
	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%
Total Chironomidae	2981.52	414.37		4108.68	486.13		3260.28	578.78		3450.16	338.95	
Chironomus sp.	36.36	16.16	1.22	66.66	14.14	1.62	618.12	571.83	18.96	240.38	189.07	6.97
Robackia cfr. *demeijerei*	66.66	16.78	2.24	48.48	19.79	1.18	72.72	17.61	2.23	62.62	7.28	1.81
Cryptochironomus sp. 1												
Cryptochironomus sp. 2	36.36	16.16	1.22	72.72	17.61	1.77	127.26	35.51	3.90	78.78	26.41	2.28
Cryptochironomus sp. 3	12.12	8.08	0.41	12.12	8.08	0.29				8.08	4.04	0.23
Saetheria cfr. *tylus*	96.96	20.60	3.25	254.52	69.86	6.19	18.18	9.26	0.56	123.22	69.48	3.57
Paracladopelma cfr. *nereis*	12.12	8.08	0.41	6.06	6.06	0.15				6.06	3.50	0.18
Paracladopelma cfr. *undine*	266.64	28.85	8.94	345.42	56.45	8.41	145.44	32.82	4.46	252.50	58.16	7.32
Paracladopelma cfr. *winnelli*												
Orthocladiini sp. 1	18.18	12.93	0.61	48.48	15.12	1.18	127.26	87.79	3.90	64.64	32.51	1.87
Psectrocladius sp.	260.58	80.83	8.74	48.48	17.61	1.18				103.02	80.01	2.99
Cladotanytarsus sp.	1848.30	337.32	61.99	2539.14	415.01	61.80	1842.24	220.58	56.51	2076.56	231.30	60.19
Polypedilum cfr. *scalaenum*	242.40	61.93	8.13	490.86	85.44	11.95	236.34	76.89	7.25	323.20	83.85	9.37
Polypedilum fallax-gr.	6.06	6.06	0.20							2.02	2.02	0.06
Monodiamesa cfr. *tuberculata*	24.24	13.40	0.81	18.18	12.93	0.44	6.06	6.06	0.19	16.16	5.34	0.47
Procladius sp.	6.06	6.06	0.20				6.06	6.06	0.19	4.04	2.02	0.12
Heterotrissocladius cfr. *changi*												
Heterotrissocladius cfr. *oliveri*												
Others	18.18		0.61	54.54		1.33	30.30		0.93	34.34		1.00

TABLE 66. (continued).

Depth Zone: 9 meters

	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total Naididae	1739.22	199.16		1363.50	208.22		1127.16	149.59		1409.96	178.21	
<u>Nais elinguis</u>	18.18	9.26	105							6.06	6.06	0.43
<u>Stylaria lacustris</u>	266.64	76.76	15.33	321.18	109.55	23.56	278.76	74.05	24.73	288.86	16.53	20.49
<u>Nais variabilis</u>	24.24	9.90	1.39	18.18	9.26	1.33	12.12	8.08	1.08	18.18	3.50	1.29
<u>Chaetogaster diaphanus</u>	793.86	147.46	45.64	539.34	117.94	39.56	309.06	71.39	27.42	547.42	140.01	38.83
<u>Piguetiella michiganensis</u>	327.24	49.64	18.82	248.46	42.80	18.22	284.82	46.11	25.27	286.84	22.76	20.34
<u>Uncinais uncinata</u>	230.28	32.32	13.24	163.62	40.45	12.00	175.74	31.88	15.59	189.88	20.50	13.47
<u>Paranais simplex</u>	18.18	9.26	1.05	30.30	13.55	2.22	12.12	8.08	1.08	20.20	5.34	1.43
<u>Paranais litoralis</u>	30.30	24.32	1.74	18.18	9.26	1.33	42.42	12.93	3.76	30.30	7.00	2.15
<u>Vejdovskyella intermedia</u>	6.06	6.06	0.35	18.18	12.93	1.33				8,08	5.34	0.57
<u>Nais bretscheri</u>	12.12	8.08	0.70	6.06	6.06		12.12	8.08	11.08	10.10	2.02	0.72
Others	12.12		0.70							4.04		0.29
Total Tubificidae	1102.92	210.27		1260.48	247.70		805.98	223.49		1056.46	133.24	
im w/o hc	745.40	122.22	67.58	860.52	183.99	68.27	630.24	161.90	78.20	745.39	66.48	70.56
im w/ hc							6.06	6.06	0.75	2.02	2.02	0.19
<u>Limnodrilus hoffmeisteri</u>	187.86	84.96	17.03	199.98	55.72	15.87	78.78	45.21	9.77	155.54	38.54	14.72
<u>Limnodrilus angustipenis</u>	24.24	13.40	2.20	54.54	16.78	4.33	24.24	18.51	3.01	34.34	10.10	3.25
<u>Limnodrilus spiralis</u>	6.06	6.06	0.55	12.12	8.08	0.96	12.12	8.08	1.50	10.10	2.02	0.96
<u>Limnodrilus profundicola</u>	84.84	16.16	7.69	48.48	33.56	3.85				44.44	24.57	4.21
<u>Limnodrilus claparedianus</u>												
<u>Potamothrix moldaviensis</u>	36.36	18.51	3.30	66.66	22.94	5.29	48.48	31.03	6.02	50.50	8.60	4.78
<u>Potamothrix vejdovskyi</u>												
<u>Peloscolex freyi</u>	12.12	8.08	1.10	12.12	8.08	0.96	6.06	6.06	0.75	10.10	2.02	0.96
<u>Peloscolex superiorensis</u>												
<u>Stylodrilus heringianus</u>				72.72	72.72					24.24	24.24	
Enchytraeidae				6.06	6.06					2.02	2.02	

TABLE 66. (continued).

Depth Zone: 9 meters

	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total Pelecypoda	42.42	12.93		78.78	31.36		109.08	19.79		76.76	19.27	
Total *Sphaerium*	6.06	6.06		6.06	6.06					4.04	2.02	
S. nitidum												
S. striatinum	6.06	6.06	100.00	6.06	6.06	100.00				4.04	2.02	100.00
S. transversum												
Total *Pisidium*	36.36	13.40		72.72	26.80		109.08	19.79		72.72	20.99	
P. fallax				6.06	6.06	8.33	24.24	9.90	22.22	10.10	7.28	13.89
P. casertanum	18.18	9.26	50.00	36.36	18.51	50.00	66.66	16.78	61.11	40.40	14.14	55.56
P. nitidum	6.06	6.06	16.67	18.18	9.26	25.00				8.08	5.34	11.11
P. henslowanum												
P. variabile	6.06	6.06	16.67							2.02	2.02	2.78
P. ferrugineum												
P. subtruncatum												
P. nitidum f. *pauperculum*							12.12	8.08	11.11	4.04	4.04	5.56
P. conventus							6.06	6.06	5.56	2.02	2.02	2.78
P. compressum				6.06	6.06	8.33				2.02	2.02	2.78
P. milium												
P. walkeri												
P. idahoense												
P. lilljeborgi												
P. adamsi				6.06	6.06	8.33				2.02	2.02	2.78
P. spp.	6.06		16.67							2.02		2.78

TABLE 66. (continued).

Depth Zone: 9 meters

	North Region			Middle Region			South Region			Total		
	$\overline{X}$	S.E.	%	$\overline{X}$	S.E.	%	$\overline{X}$	S.E.	%	$\overline{X}$	S.E.	%
Total _Pontoporeia affinis_	1611.96	168.33		1315.02	188.86		2272.50	230.36		1733.16	282.97	
P. affinis < 3 mm	1611.96	168.33	100.00	1315.02	188.86	100.00	2048.28	323.81	90.13	1658.42	212.94	95.69
P. affinis 3-5 mm												
P. affinis 5-7 mm												
P. affinis > 7 mm												
Total Gastropoda	36.36	9.90		18.18	18.18		30.30	13.55		28.28	5.34	
Valvata sincera	30.30	10.10	83.33	18.18	18.18	100.00	12.12	8.08	40.00	20.20	5.34	71.43
Amnicola sp.	6.06	6.06	16.67				18.18	9.26	60.00	8.08	5.34	28.57
Lymnaea sp.												
Total Hirudinea												
Helobdella stagnalis												
Other Hirudinea												
Total Animals	7532.58	626.98		8162.82	609.16		7611.36	940.56		7764.88	203.93	

TABLE 67. Abundance of the most numerous taxa found near the J.H. Campbell Plant at 12 m in June 1977 ($\overline{x}$ = mean, S.E. = standard error).

Depth Zone: 12 meters

	North Region			Middle Region			South Region			Total		
	$\overline{x}$	S.E.	%	$\overline{x}$	S.E.	%	$\overline{x}$	S.E.	%	$\overline{x}$	S.E.	%
Total Chironomidae	696.90	85.34		538.67	58.63		721.14	91.88		652.24	57.21	
Chironomus sp.							72.72	49.31	10.08	24.24	24.24	3.72
Robackia cfr. *demeijerei*	6.06	6.06	0.87	13.47	12.78	2.50	42.42	15.78	5.88	20.65	11.09	3.17
Cryptochironomus sp. 1							6.06	6.06	0.84	2.02	2.02	0.31
Cryptochironomus sp. 2	18.18	9.26	2.61	74.07	20.94	13.75	54.54	19.06	7.56	48.93	16.38	7.50
Cryptochironomus sp. 3												
Saetheria cfr. *tylus*	24.24	9.09	3.48	26.93	13.92	5.00	54.54	30.57	7.56	35.24	9.68	5.40
Paracladopelma cfr. *nereis*												
Paracladopelma cfr. *undine*	96.96	27.40	13.91	134.67	24.95	25.00	96.96	20.60	13.45	109.53	12.57	16.79
Paracladopelma cfr. *winnelli*							6.06	6.06	0.84	2.02	2.02	0.31
Orthocladiini sp. 1	6.06	6.06	0.87				30.30	13.55	4.20	12.12	9.26	1.86
Psectrocladius sp.				6.73	6.39	1.25				2.24	2.24	0.34
Cladotanytarsus sp.	42.42	23.99	6.09	94.27	19.43	17.50	199.98	47.84	27.73	112.22	46.36	17.21
Polypedilum cfr. *scalaenum*	230.28	68.68	33.04	74.07	28.17	13.75	115.14	42.80	15.97	139.83	46.75	21.44
Polypedilum fallax-gr.	48.48	12.12	6.96				6.06	6.06	0.84	18.18	15.25	2.79
Monodiamesa cfr. *tuberculata*	139.38	23.99	20.00	67.33	22.36	12.50	18.18	12.93	2.52	74.96	35.19	11.49
Procladius sp.	24.24	9.09	3.48							8.08	8.08	1.24
Heterotrissocladius cfr. *changi*												
Heterotrissocladius cfr. *oliveri*												
Others	24.24		3.48	20.20		3.35	6.06		0.84	16.83		2.50

TABLE 67. (continued).

	North Region			Middle Region			South Region			Total		
Depth Zone: 12 meters	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total Naididae	618.12	106.43		619.47	110.41		902.94	99.14		713.51	94.72	
Nais elinguis												
Stylaria lacustris	36.36	9.90	5.88	20.20	13.55	3.26	163.62	65.80	18.12	73.39	45.35	10.29
Nais variabilis				13.47	8.91	2.17	6.06	6.06	0.67	6.51	3.89	0.91
Chaetogaster diaphanus	115.14	45.57	18.63	127.93	42.25	20.65	290.88	45.89	32.21	177.98	56.57	24.94
Piguetiella michiganensis	339.36	59.38	54.90	222.20	49.79	35.87	163.62	33.86	18.12	241.73	51.66	33.88
Uncinais uncinata	96.96	34.04	15.69	107.73	34.25	17.39	84.84	25.87	9.40	96.51	6.61	13.53
Paranais simplex				20.20	9.58	3.26	36.36	16.16	4.03	18.85	10.52	2.64
Paranais litoralis	18.18	9.26	2.94	60.60	19.16	9.78	30.30	13.55	3.36	36.36	12.61	5.10
Vejdovskyella intermedia				20.20	13.55	3.26	90.90	38.59	10.07	37.03	27.56	5.19
Nais bretscheri	12.12	8.08	1.96	6.73	6.73	1.09	30.30	13.55	3.36	16.38	7.13	2.30
Others				20.20	10.10	3.26	12.12	8.08	1.34	10.77	5.87	1.51
Total Tubificidae	721.14	186.77		390.53	90.96		284.82	73.97		465.50	131.41	
im w/o hc	478.74	129.80	66.39	316.47	90.28	81.04	230.28	63.11	80.85	341.83	72.84	73.43
im w/ hc	6.06	6.06	0.84							2.02	2.02	0.43
Limnodrilus hoffmeisteri	90.90	35.28	12.61	13.47	8.45	3.45	30.30	13.55	10.64	44.89	23.51	9.64
Limnodrilus angustipenis	12.12	8.08	1.68	20.20	13.55	5.17	6.06	6.06	2.13	12.79	4.10	2.75
Limnodrilus spiralis	6.06	6.06	0.84	6.37	6.39	1.63	12.12	8.08	4.26	8.18	1.97	1.76
Limnodrilus profundicola	36.36	16.16	5.04	20.20	13.55	5.17				18.85	10.52	4.05
Limnodrilus claparedianus												
Potamothrix moldaviensis	36.36	20.60	5.04	13.47	8.45	3.45	6.06	6.06	2.13	18.63	9.12	4.00
Potamothrix vejdovskyi	48.48	26.80	6.72							16.16	16.16	3.47
Peloscolex freyi	6.06	6.06	0.84							2.02	2.02	0.43
Peloscolex superiorensis												
Stylodrilus heringianus												
Enchytraeidae	6.06	6.06					12.12	8.08		6.06	3.50	

TABLE 67. (continued).

Depth Zone: 12 meters

	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total Pelecypoda	969.60	155.68		511.73	59.92		363.60	69.97		614.98	182.40	
Total *Sphaerium*	6.06	6.06		6.73	6.73					4.26	2.14	
S. nitidum												
S. striatinum	6.06	6.06	100.00	6.73	6.73	100.00				4.26	2.14	100.00
S. transversum												
Total *Pisidium*	963.54	156.59		505.00	59.07		363.60	69.97		610.71	181.07	
P. fallax	218.16	52.05	22.64	87.53	22.83	17.33	72.72	23.56	20.00	126.14	46.21	20.65
P. casertanum	363.60	82.30	37.74	121.20	31.94	24.00	145.44	32.82	40.00	210.08	77.08	34.40
P. nitidum	163.62	30.03	16.98	208.73	85.77	41.33	6.06	6.06	1.67	126.14	61.43	20.65
P. henslowanum	12.12	8.08	1.26				24.24	16.16	6.67	12.12	7.00	1.98
P. variabile	66.66	29.20	6.92	47.13	13.47	9.33	6.06	6.06	1.67	39.95	17.86	6.54
P. ferrugineum	6.06	6.06	0.63							2.02	2.02	0.33
P. subtruncatum	6.06	6.06	0.63							2.02	2.02	0.33
P. nitidum f. *pauperculum*	24.24	18.51	2.52	13.47	13.47	2.67	36.36	13.40	10.00	24.69	6.61	4.04
P. conventus	36.36	20.60	3.77				48.48	23.56	13.33	28.28	14.57	4.63
P. compressum	6.06	6.06	0.63							2.02	2.02	0.33
P. milium				6.73	6.73	1.33				2.24	2.24	0.37
P. walkeri												
P. idahoense												
P. lilljeborgi												
P. adamsi												
P. spp.	60.60		6.28	20.20		4.00	24.24		6.66	35.01		5.74

TABLE 67. (continued).

Depth Zone: 12 meters

	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total *Pontoporeia affinis*	5126.76	545.64		5110.60	557.39		4229.88	512.76		4822.41	296.30	
P. affinis < 3 mm	5096.46	542.36	99.41	5103.87	555.72	99.87	4229.88	512.76	100.00	4810.07	290.10	99.74
P. affinis 3-5 mm												
P. affinis 5-7 mm	30.30	13.55	0.59	6.39	6.39	0.13				12.22	9.22	0.26
P. affinis > 7 mm												
Total Gastropoda	309.06	51.46		168.33	32.88		175.74	42.80		217.71	45.73	
Valvata sincera	260.58	40.45	84.31	154.87	30.47	92.00	133.32	33.56	75.86	182.92	39.32	84.02
Amnicola sp.	48.48	17.61	15.68	13.47	8.45	8.00	42.42	20.30	24.14	34.79	10.80	15.98
Lymnaea sp.												
Total Hirudinea	12.12	8.08					12.12	12.12		8.08	4.04	
Helobdella stagnalis	6.06	6.06	50.00				6.06	6.06	50.00	4.04	2.02	50.00
Other Hirudinea	6.06	6.06	50.00				6.06	6.06	50.00	4.04	2.02	50.00
Total Animals	8465.82	938.47		7346.07	604.39		6720.54	599.26		7510.81	510.51	

TABLE 68. Abundance of the most numerous taxa found near the Campbell Plant at 15 m in June 1977($\bar{x}$ = mean, S.E. = standard error).

Depth Zone: 15 meters

	North Region			Middle Region			South Region			Total		
	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%
Total Chironomidae	412.08	50.94		478.74	95.80		763.56	122.94		551.46	107.78	
Chironomus sp.	6.06	6.06	1.47							2.02	2.02	0.37
Robackia cfr. *demeijeriei*	12.12	12.12	2.94	6.06	6.06	1.27	18.18	18.18	2.38	12.12	3.50	2.20
Cryptochironomus sp. 1												
Cryptochironomus sp. 2	6.06	6.06	1.47	36.36	18.51	7.59	6.06	6.06	0.79	16.16	10.10	2.93
Cryptochironomus sp. 3												
Saetheria cfr. *tylus*	6.06	6.06	1.47	6.06	6.06	1.27	6.06	6.06	0.79	6.06	0	1.10
Paracladopelma cfr. *nereis*												
Paracladopelma cfr. *undine*	36.36	13.40	8.82	6.06	6.06	1.27	24.24	13.40	3.17	22.22	8.80	4.03
Paracladopelma cfr. *winnelli*	12.12	8.08	2.94	6.06	6.06	1.27	54.54	16.78	7.14	24.24	15.25	4.40
Orthocladiini sp. 1				6.06	6.06	1.27				2.02	2.02	0.37
Psectrocladius sp.							6.06	6.06	0.79	2.02	2.02	0.37
Cladotanytarsus sp.	6.06	6.06	1.47				6.06	6.06	0.79	4.04	2.02	0.73
Polypedilum cfr. *scalaenum*	30.30	13.55	7.35	30.30	16.29	6.33	12.12	8.08	1.59	24.24	6.06	4.40
Polypedilum fallax-gr.	115.14	34.34	27.94	163.62	43.37	34.18	460.56	108.86	60.32	246.44	107.97	44.69
Monodiamesa cfr. *tuberculata*	139.38	23.99	33.82	175.74	48.18	36.71	127.26	43.75	16.67	147.46	14.57	26.74
Procladius sp.	12.12	8.08	2.94	24.24	9.09	5.06	6.06	6.06	0.79	14.14	5.34	2.56
Heterotrissocladius cfr. *changi*	24.24	13.40	5.08	12.12	8.08	2.53	36.36	13.40	4.76	24.24	7.00	4.40
Heterotrissocladius cfr. *oliveri*												
Others	6.06		1.47							2.02		0.37

TABLE 68. (continued).

	Depth Zone: 15 meters											
	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total Naididae	296.94	106.30		502.98	101.42		490.86	115.85		430.26	66.75	
<u>Nais elinguis</u>												
<u>Stylaria lacustris</u>	24.24	24.24	8.16	12.12	12.12	2.38				12.12	7.00	2.80
<u>Nais variabilis</u>												
<u>Chaetogaster diaphanus</u>	24.24	18.51	8.16	60.60	36.13	11.90	48.48	31.03	9.88	44.44	10.69	10.28
<u>Piguetiella michiganensis</u>	109.08	44.99	36.73	254.52	73.83	50.00	127.26	29.19	25.93	163.61	45.76	37.85
<u>Uncinais uncinata</u>	103.02	43.37	34.69	48.48	19.79	9.64	24.24	9.90	4.94	58.58	23.30	13.62
<u>Paranais simplex</u>				12.12	8.08	2.38	199.98	76.15	40.74	70.70	64.73	16.36
<u>Paranais litoralis</u>	12.12	8.08	4.08	84.84	34.04	16.87	42.42	12.93	8.64	46.46	21.09	10.80
<u>Vejdovskyella intermedia</u>	6.06	6.06	2.04	12.12	8.08	2.38	18.18	12.93	3.70	12.12	3.50	2.80
<u>Nais bretscheri</u>	6.06	6.06	2.04				12.12	12.12	2.47	6.06	3.50	1.40
Others	12.12	8.08	4.08	18.18	9.26	3.57	18.18	18.18	3.70	16.16	2.02	3.74
Total Tubificidae	969.60	306.35		1248.36	394.52		987.78	195.44		1068.58	90.04	
im w/o hc	757.50	246.12	78.13	896.88	287.92	71.84	678.72	144.48	68.71	777.70	63.78	72.78
im w/ hc	36.36	18.51	3.75	6.06	6.06	0.49	54.54	27.77	5.52	32.32	14.14	3.03
<u>Limnodrilus hoffmeisteri</u>	84.84	52.83	8.75	78.78	30.03	6.31	115.14	42.80	11.66	92.92	11.25	8.71
<u>Limnodrilus angustipenis</u>				30.30	24.32	2.43	6.06	6.06	0.61	12.12	9.26	1.14
<u>Limnodrilus spiralis</u>	6.06	6.06	0.63				6.06	6.06	0.61	4.04	2.02	0.38
<u>Limnodrilus profundicola</u>	12.12	8.08	1.25	36.36	24.24	2.91				16.16	10.69	1.52
<u>Limnodrilus claparedianus</u>												
<u>Potamothrix moldaviensis</u>	36.36	16.16	3.75	169.68	56.99	13.59	78.78	36.19	7.98	94.94	39.33	8.90
<u>Potamothrix vejdovskyi</u>	36.36	13.40	3.75	30.30	13.55	2.43	42.42	20.30	4.29	36.36	3.50	3.41
<u>Peloscolex freyi</u>												
<u>Peloscolex superiorensis</u>							6.06	6.06	0.61	2.02	2.02	0.19
<u>Stylodrilus heringianus</u>	745.38	188.86		769.62	267.53		1284.72	336.17		933.24	175.88	
Enchytraeidae							6.06	6.06		2.02	2.02	

TABLE 68. (continued).

Depth Zone: 15 meters

	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total Pelecypoda	1733.16	256.98		1963.44	356.14		1284.72	343.14		1660.44	199.27	
Total *Sphaerium*	24.24	13.40		18.18	12.93		30.30	30.30		24.24	3.50	
S. nitidum	6.06	6.06	25.00							2.02	2.02	8.33
S. striatinum	18.18	12.93	75.00	12.12	12.12	66.67				10.10	5.34	41.67
S. transversum				6.06	6.06	33.33	30.30	30.30	100.00	12.12	9.26	50.00
Total *Pisidium*	1708.92	250.97		1945.26	357.65		1254.42	327.47		1636.20	202.72	
P. fallax	78.78	25.63	4.61	145.44	37.47	7.48	96.96	24.24	7.73	107.06	19.89	6.54
P. casertanum	854.46	145.23	50.00	660.54	107.82	33.96	472.68	134.24	37.68	662.56	110.22	40.49
P. nitidum	272.70	55.14	15.96	460.56	84.84	23.98	193.92	70.44	15.46	309.06	79.09	18.89
P. henslowanum	139.38	36.19	8.16	193.92	55.54	9.97	96.96	28.85	7.73	143.42	28.06	8.77
P. variabile	30.30	16.29	1.77	72.72	21.76	3.74	127.26	38.85	10.14	76.76	28.06	4.69
P. ferrugineum												
P. subtruncatum	12.12	8.08	0.71	6.06	6.06	0.31	6.06	6.06	0.48	8.08	2.02	0.49
P. nitidum f. *pauperculum*	24.24	13.40	1.42	133.32	43.14	6.85	84.84	30.23	6.76	80.80	31.55	4.94
P. conventus	103.02	35.05	6.03	139.38	64.55	7.17	84.84	48.82	6.76	109.08	16.03	6.67
P. compressum	6.06	6.06	0.35							2.02	2.02	0.12
P. milium												
P. walkeri	6.06	6.06	0.35							2.02	2.02	0.12
P. idahoense												
P. lilljeborgi							42.42	23.99	3.38	14.14	14.14	0.86
P. adamsi												
P. spp.	181.80		10.63	115.14		5.92	48.48		3.86	115.14		7.03

TABLE 68. (continued).

Depth Zone: 15 meters

	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total *Pontoporeia affinis*	8774.88	643.79		12592.68	1115.94		8702.16	1149.28		10023.24	1284.89	
P. affinis < 3 mm	8538.54	609.52	97.31	12477.54	1121.14	99.09	8550.66	1160.87	98.26	9855.58	1310.98	98.33
P. affinis 3-5 mm	48.48	28.28	0.55				48.48	12.12	0.56	32.32	16.16	0.32
P. affinis 5-7 mm	187.86	45.57	2.14	115.14	26.26	0.91	103.02	25.63	1.18	135.34	26.49	1.35
P. affinis > 7 mm												
Total Gastropoda	260.58	55.72		266.64	66.51		157.56	38.54		228.26	35.39	
Valvata sincera	212.10	44.49	81.40	206.04	55.83	77.27	145.44	34.04	92.31	187.86	21.28	82.30
Amnicola sp.	48.48	15.12	18.60	60.60	27.10	22.73				40.40	14.57	17.69
Lymnaea sp.												
Total Hirudinea	42.42	23.99		36.36	9.90		24.24	13.40		34.34	5.34	
Helobdella stagnalis												
Other Hirudinea	42.42	23.99	100.00	36.36	9.90	100.00	24.24	13.40	100.00	34.34	5.34	
Total Animals	13247.16	972.80		17864.88	1218.14		13731.96	1794.49		14945.98	1463.13	

TABLE 69. Abundance of the most numerous taxa found near the J. H. Campbell Power Plant at 20 m in June 1977 ($\bar{x}$ = mean, S.E. = standard error).

	Depth Zone: 20 meters											
	North Region			Middle Region			South Region			Total		
	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%
Total Chironomidae	551.46	62.88		424.20	46.94		593.88	77.61		523.18	50.98	
Chironomus sp.												
Robackia cfr. *demeijerei*							6.06	6.06	1.02	2.02	2.02	0.39
Cryptochironomus sp. 1												
Cryptochironomus sp. 2							6.06	6.06	1.02	2.02	2.02	0.39
Cryptochironomus sp. 3												
Saetheria cfr. *tylus*	6.06	6.06	1.10							2.02	2.02	0.39
Paracladopelma cfr. *nereis*												
Paracladopelma cfr. *undine*	6.06	6.06	1.10	12.12	12.12	2.86	6.06	6.06	1.02	8.08	2.02	1.54
Paracladopelma cfr. *winnelli*	30.30	10.10	5.49	18.18	9.26	4.29	48.48	15.12	8.16	32.32	8.80	6.18
Orthocladiini sp. 1												
Psectrocladius sp.												
Cladotanytarsus sp.							6.06	6.06	1.02	2.02	2.02	0.39
Polypedilum cfr. *scalaenum*				6.06	6.06	1.43	6.06	6.06	1.02	4.04	2.02	0.77
Polypedilum fallax-gr.	199.98	39.43	36.26	236.34	44.67	55.71	266.64	60.73	44.90	234.32	19.27	44.79
Monodiamesa cfr. *tuberculata*	133.32	26.80	24.18	84.84	27.40	20.00	96.96	18.51	16.33	105.04	14.57	20.08
Procladius sp.	18.18	9.26	3.30				24.24	13.40	4.08	14.14	7.28	2.70
Heterotrissocladius cfr. *changi*	151.50	28.92	27.47	66.66	31.88	15.71	127.24	47.32	21.43	115.13	25.23	22.01
Heterotrissocladius cfr. *oliveri*	6.06	6.06	1.10							2.02	2.02	0.39
Others												

TABLE 69. (continued).

	Depth Zone: 20 meters											
	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total Naididae	109.08	42.18		109.08	89.43		224.22	73.42		147.46	38.38	
Nais elinguis				6.06	6.06	5.56				2.02	2.02	1.37
Stylaria lacustris												
Nais variabilis												
Chaetogaster diaphanus	6.06	6.06	5.56	24.24	13.40	22.22	12.12	8.08	5.41	14.14	5.34	9.59
Piguetiella michiganensis	18.18	9.26	16.67				18.18	12.93	8.11	12.12	6.06	8.22
Uncinais uncinata												
Paranais simplex	36.36	20.60	33.33	54.54	21.09	50.00	151.50	68.95	67.57	80.80	35.74	54.79
Paranais litoralis	48.48	26.80	44.44	24.24	9.09	22.22	36.36	24.24	16.22	36.36	7.00	24.66
Vejdovskyella intermedia							6.06	6.06	2.70	2.02	2.02	1.37
Nais bretscheri												
Others												
Total Tubificidae	145.44	62.06		115.14	26.26		515.10	105.06		258.56	128.57	
im w/o hc	103.02	40.45	70.83	66.66	21.09	57.89	315.12	92.92	61.18	161.60	77.47	62.50
im w/ hc	12.12	12.12	8.33				24.24	24.24	4.71	12.12	7.00	4.69
Limnodrilus hoffmeisteri	12.12	8.08	8.33	30.30	13.55	26.32	121.20	40.40	23.53	54.54	33.74	21.09
Limnodrilus angustipenis												
Limnodrilus spiralis							6.06	6.06	1.18	2.02	2.02	0.78
Limnodrilus profundicola							6.06	6.06	1.18	2.02	2.02	0.78
Limnodrilus claparedianus							6.06	6.06	1.18	2.02	2.02	0.78
Potamothrix moldaviensis				18.18	12.93	15.78	18.18	12.93	3.53	12.12	6.06	4.69
Potamothrix vejdovskyi	12.12	8.08	8.33				12.12	8.08	2.35	8.08	4.04	3.13
Peloscolex freyi												
Peloscolex superiorensis	6.06	6.06	4.17				6.06	6.06	1.18	4.04	2.02	1.56
Stylodrilus heringianus	2060.40	611.10		1181.70	394.00		2908.80	845.41		2050.30	498.60	
Enchytraeidae	6.06	6.06		6.06	6.06		6.06	6.06		6.06	0	

TABLE 69 . (continued).

Depth Zone: 20 meters

	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total Pelecypoda	1290.78	353.01		884.76	262.32		2290.68	567.39		1488.74	417.75	
Total *Sphaerium*	84.84	43.51		30.30	13.55		218.16	80.39		111.10	55.80	
S. nitidum	66.66	40.85	78.57	12.12	8.08	40.00	181.80	69.97	83.33	86.86	50.01	78.18
S. striatinum	18.18	12.93	21.43	12.12	8.08	40.00	36.36	20.60	16.67	22.22	7.28	20.00
S. transversum				6.06	6.06	20.00				2.02	2.02	1.82
Total *Pisidium*	1205.94	312.60		854.46	252.37		2072.50	500.53		1377.63	361.95	
P. fallax	12.12	8.08	1.01	42.42	18.18	4.96	60.60	15.65	2.92	38.38	14.14	2.79
P. casertanum	412.08	101.32	34.17	181.80	65.14	21.28	84.84	34.04	4.09	226.24	97.04	16.42
P. nitidum	230.28	85.13	19.10	254.52	87.96	29.79	587.82	167.07	28.36	357.54	115.35	25.95
P. henslowanum	36.36	16.16	3.02	42.42	20.30	4.96	78.78	28.64	3.80	52.52	13.25	3.81
P. variabile	42.42	23.99	3.52	60.60	23.90	7.09	157.56	31.55	7.60	86.86	35.74	6.31
P. ferrugineum	66.66	36.64	5.53	6.06	6.06	0.71	24.24	18.51	1.17	32.32	17.95	2.35
P. subtruncatum												
P. nitidum f. *pauperculum*	12.12	8.08	1.01	66.66	26.26	7.80	121.20	45.17	5.85	66.66	31.49	4.84
P. conventus	139.38	63.27	11.56	163.62	71.16	19.15	793.86	211.56	38.30	365.62	214.23	26.54
P. compressum												
P. milium	18.18	12.93	1.51							6.06	6.06	0.44
P. walkeri												
P. idahoense												
P. lilljeborgi	54.54	30.57	4.52				54.54	22.94	2.63	36.36	18.18	2.64
P. adamsi												
P. spp.	169.68		14.07	18.18		2.13	96.96		4.67	94.94		6.89

TABLE 69. (continued).

Depth Zone: 20 meters

	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total *Pontoporeia affinis*	5054.04	889.22		5344.92	567.03		5963.04	924.10		5454.00	268.01	
P. affinis < 3 mm	3048.18	627.18	60.31	4145.04	600.13	77.55	4769.22	746.53	79.88	3987.48	503.03	73.11
P. affinis 3-5 mm	1066.56	322.34	21.10	363.60	57.84	6.80	721.14	221.73	12.04	717.10	202.94	13.15
P. affinis 5-7 mm	933.24	151.76	18.47	733.20	132.00	13.72	472.68	126.50	7.93	713.04	133.33	13.07
P. affinis > 7 mm												
Total Gastropoda	24.24	9.09		18.18	12.93		187.86	84.48		76.76	55.58	
Valvata sincera	18.18	9.26	75.00	18.18	12.93	100.00	175.74	79.50	93.55	70.70	52.52	92.11
Amnicola sp.	6.06	6.06	25.00				12.12	8.08	6.45	6.06	3.50	7.89
Lymnaea sp.												
Total Hirudinea	18.18	12.93		12.12	12.12		24.24	13.40		18.18	3.50	
Helobdella stagnalis	12.12	12.12	66.67				12.12	8.08	50.00	8.08	4.04	44.44
Other Hirudinea	6.06	6.06	33.33	12.12	12.12	100.00	12.12	8.08	50.00	10.10	2.02	55.56
Total Animals	9277.86	1436.57		8120.00	814.99		12768.42	2256.59		10055.43	1397.07	

TABLE 70. Abundance of the most numerous taxa found near the J. H. Campbell Power Plant at 25 m in June 1977 ($\bar{x}$ = mean, S.E. = standard error).

Depth Zone: 25 meters

	North Region			Middle Region			South Region			Total		
	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%	$\bar{x}$	S.E.	%
Total Chironomidae	690.87	102.29		418.12	78.99		666.60	75.04		591.86	87.15	
Chironomus sp.												
Robackia cfr. *demeijerei*												
Cryptochironomus sp. 1												
Cryptochironomus sp. 2							6.06	6.06	0.91	2.02	2.02	0.34
Cryptochironomus sp. 3												
Saetheria cfr. *tylus*												
Paracladopelma cfr. *nereis*												
Paracladopelma cfr. *undine*	6.06	6.06	0.88							2.02	2.02	0.34
Paracladopelma cfr. *winnelli*	90.90	20.70	13.16	60.60	20.20	14.49	78.78	23.99	11.82	76.76	8.80	12.97
Orthocladiini sp. 1												
Psectrocladius sp.												
Cladotanytarsus sp.												
Polypedilum cfr. *scalaenum*							6.06	6.06	0.91	2.02	2.02	0.34
Polypedilum fallax-gr.	121.20	39.38	17.54	72.72	32.32	17.39	230.26	75.47	34.54	141.39	46.59	23.89
Monodiamesa cfr. *tuberculata*	127.26	49.08	18.42	78.78	20.30	18.84	90.90	37.52	13.64	98.98	14.57	16.72
Procladius sp.	42.42	20.30	6.14				30.30	20.70	4.55	24.24	12.61	4.10
Heterotrissocladius cfr. *changi*	260.58	30.03	37.72	206.04	46.24	49.28	181.80	46.06	27.27	216.14	23.30	36.52
Heterotrissocladius cfr. *oliveri*	30.30	20.70	4.39				24.24	16.16	3.64	18.18	9.26	3.07
Others							12.12		1.82	4.04		0.68

TABLE 70. (continued).

	Depth Zone: 25 meters											
	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total Naididae	30.30	18.62		18.18	9.26		42.42	28.64		30.30	7.00	
Nais elinguis												
Stylaria lacustris												
Nais variabilis												
Chaetogaster diaphanus												
Piguetiella michiganensis				6.06	6.06	33.33				2.02	2.02	6.67
Uncinais uncinata												
Paranais simplex							12.12	12.12	28.57	4.04	4.04	13.33
Paranais litoralis	24.24	18.51	80.00	12.12	8.08	66.67	12.12	8.08	28.57	16.16	4.04	53.33
Vejdovskyella intermedia	6.06	6.06	20.00				18.18	12.93	42.86	8.08	5.34	26.67
Nais bretscheri												
Others												
Total Tubificidae	290.88	130.34		115.14	39.84		369.66	84.96		258.56	75.23	
im w/o hc	205.34	97.56	70.59	48.48	17.61	42.11	206.04	40.60	55.74	153.29	52.40	59.28
im w/ hc	30.30	16.29	10.42	36.36	18.51	31.58	66.66	31.88	18.03	44.44	11.25	17.19
Limnodrilus hoffmeisteri	12.12	8.08	4.17	12.12	8.08	10.53	72.72	23.56	19.67	32.32	20.20	12.50
Limnodrilus angustipenis												
Limnodrilus spiralis	18.18	12.93	6.25				6.06	6.06	1.64	8.08	5.34	3.13
Limnodrilus profundicola				6.06	6.06	5.26				2.02	2.02	0.78
Limnodrilus claparedianus												
Potamothrix moldaviensis												
Potamothrix vejdovskyi	18.18	12.93	6.25				12.12	8.08	3.28	10.10	5.34	3.91
Peloscolex freyi												
Peloscolex superiorensis	6.06	6.06	2.08	12.12	8.08	10.53	6.06	6.06	1.64	8.08	2.02	3.13
Stylodrilus heringianus	2914.86	442.51		2748.20	492.28		3205.74	476.35		2956.27	133.69	
Enchytraeidae							6.06	6.06		2.02	2.02	

TABLE 70. (continued).

Depth Zone: 25 meters

	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total Pelecypoda	2793.66	398.86		1181.70	205.65		2872.44	563.52		2282.60	550.92	
Total *Sphaerium*	206.04	61.40		48.48	19.79		187.86	93.64		147.46	49.77	
S. nitidum	163.62	59.27	79.41				151.50	96.56	80.65	105.04	52.64	71.23
S. striatinum	42.42	15.78	20.59	48.48	19.79	100.00	36.36	20.60	19.35	42.42	3.50	28.77
S. transversum												
Total *Pisidium*	2587.62	352.44		1133.22	191.43		2684.58	498.83		2135.14	501.74	
P. fallax	6.06	6.06	0.23	18.18	9.26	1.60	24.24	18.51	0.90	16.16	5.34	0.76
P. casertanum	327.24	84.84	12.65	115.14	33.13	10.16	287.76	78.34	10.72	243.38	65.12	11.40
P. nitidum	612.06	81.03	23.65	339.36	64.64	29.95	775.68	148.11	28.89	575.70	127.26	26.96
P. henslowanum	103.02	39.43	3.98	18.18	12.93	1.60	30.30	13.55	1.13	50.50	26.49	2.37
P. variabile	66.66	21.09	2.58	72.72	38.11	6.42	30.30	18.62	1.13	56.56	13.25	2.65
P. ferrugineum	206.04	45.35	7.96				36.36	20.60	1.35	80.80	63.49	3.78
P. subtruncatum	30.30	10.10	1.17	24.24	16.16	2.14	18.18	9.26	0.68	24.24	3.50	1.14
P. nitidum f. *pauperculum*				18.18	12.93	1.60	24.24	13.40	0.90	14.14	7.28	0.66
P. conventus	472.68	90.70	18.27	369.66	62.23	32.62	915.06	174.11	34.09	585.80	167.29	27.44
P. compressum	6.06	6.06	0.23							2.02	2.02	0.09
P. milium	12.12	8.08	0.47							4.04	4.04	0.19
P. walkeri												
P. idahoense												
P. lilljeborgi	96.96	27.40	3.75	6.06	6.06	0.53	42.42	23.99	1.58	48.48	26.41	2.27
P. adamsi												
P. spp.	648.42		25.06	151.50		13.37	509.04		18.96	436.32		20.44

TABLE 70 . (continued).

Depth Zone: 25 meters

	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Total *Pontoporeia affinis*	6360.00	702.95		3817.80	373.13		6193.32	793.59		5457.04	821.03	
P. affinis < 3 mm	3405.72	567.10	53.55	2060.40	315.15	53.97	3866.28	636.85	62.43	3110.80	541.77	57.01
P. affinis 3-5 mm	1545.30	193.38	24.30	618.12	95.09	16.19	1105.92	318.52	17.86	1086.78	267.78	19.97
P. affinis 5-7 mm	1411.98	174.72	22.20	1139.28	79.17	29.84	1212.00	74.49	19.57	1254.42	81.53	22.99
P. affinis > 7 mm							12.12	8.08	0.20	4.04	4.04	0.07
Total Gastropoda	12.12	8.08		18.18	9.26		36.36	20.60		22.22	7.28	
Valvata sincera	12.12	8.08	100.00	6.06	6.06	33.33	36.36	20.60	100.00	18.18	9.26	81.82
Amnicola sp.												
Lymnaea sp.				12.12	8.08	66.67				4.04	4.04	18.18
Total Hirudinea	24.24	13.40		12.12	8.08					12.12	7.00	
Helobdella stagnalis	18.18	9.26	66.67							6.06	6.06	50.00
Other Hirudinea	6.06	6.06	33.33	12.12	8.08	100.00				6.06	3.50	50.00
Total Animals	13125.96	1493.28		8374.92	883.26		13398.66	1576.13		11633.18	1631.03	

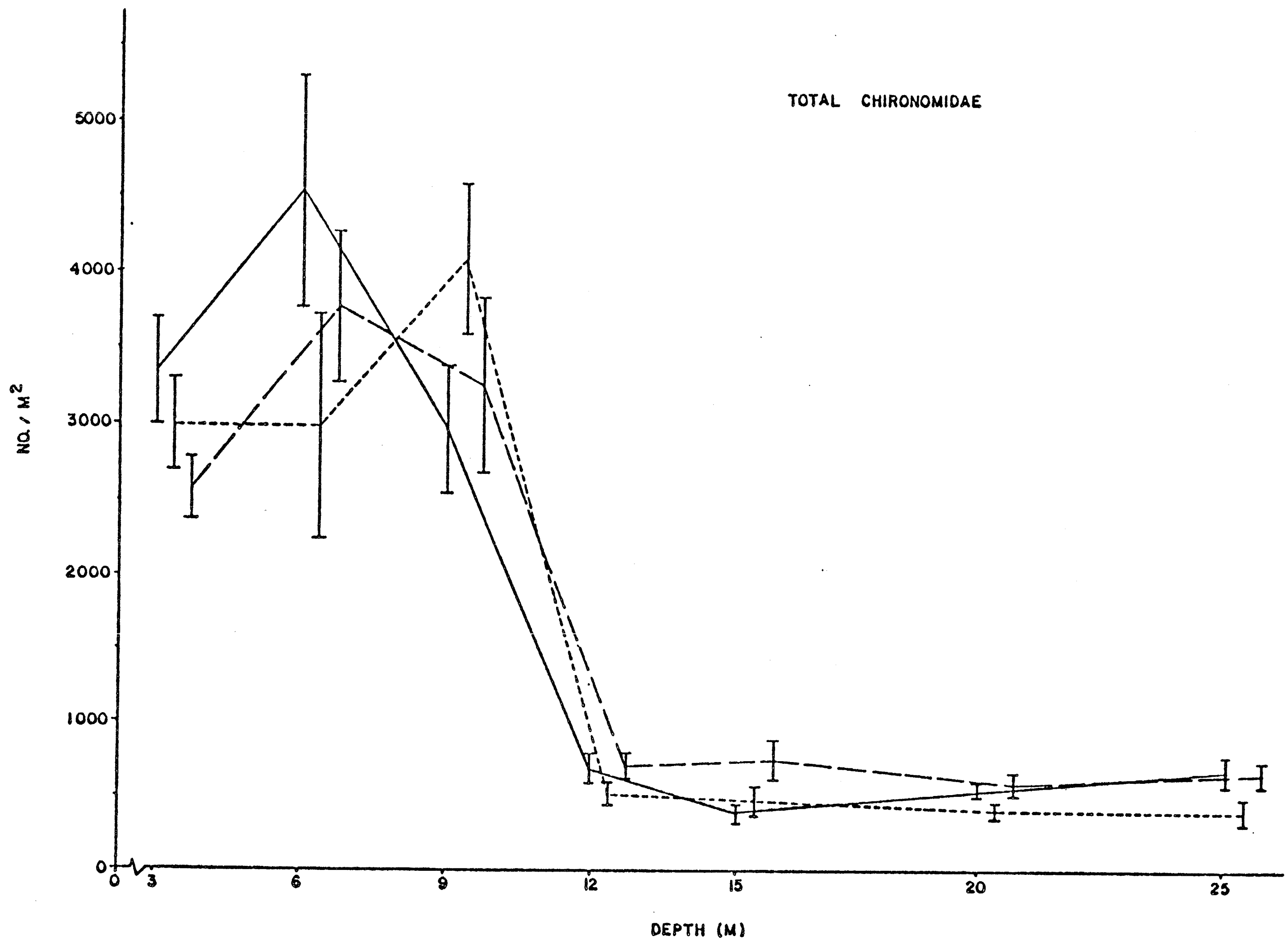


FIG. 155. Abundance of chironomids in the north (———), middle (- - - -) and south (— — —) regions over depths near the J. H. Campbell Power Plant in June 1977. Standard error denoted by vertical bar.

The greatest number of chironomid taxa (21) at any depth sampled was found at 9 m. The dominant taxa was <u>Cladotanytarsus</u> sp. (1800-2500/m^2) which comprised 60% of the chironomids present at this depth and 27% of all the animals present at 9 m. Chironomids present in moderate abundance were <u>Chironomus</u> sp., <u>P</u>. cfr. <u>undine</u> an <u>Polypedilum</u> cfr. <u>scalaenum</u>.

Dominance of the chironomid community at 12 m was shared by three of the 17 chironomid taxa collected: <u>P</u>. cfr. <u>scalaenum</u> (74-230/m^2), <u>Cladotanytarsus</u> sp. (40-200/m^2) and <u>P</u>. cfr. <u>undine</u> (97-135/m^2). In addition to these <u>Monodiamesa</u> cfr. <u>tuberculata</u>, <u>Cryptochironomus</u> sp. 2 and <u>S</u>. cfr. <u>tylus</u> each comprised at least 5% or more of the chironomid population.

Of the 15 chironomid taxa collected at 15 m there were two dominant chironomids: <u>Polypedilum</u> fallax-gr (43-460/m^2) and <u>M</u>. cfr. <u>tuberculata</u> (127-176/m^2). These two taxa combined accounted for 71% of the total number of chironomids found at 15 m. None of the other 13 chironomid taxa occurred in numbers greater than 5% of the total number of chironomids present.

Of the 12 chironomid taxa collected at 20 m, <u>P</u>. fallax-gr. (200-266/m^2), <u>Heterotrissocladius</u> cfr. <u>changi</u> (67-152/m^2) and <u>M</u>. cfr. <u>tuberculata</u> (85-133/m^2) were most abundant. These three comprised 87% of the chironomids present at 20 m. <u>Paracladopelma</u> cfr. <u>winnelli</u> occurred in moderate abundance (32/m^2).

The least number of chironomid taxa (10) were found at 25 m. <u>H</u>. cfr. <u>changi</u> (182-260/m^2) was the most abundant chironomid, followed by <u>P</u>. fallax-gr. (72-230/m^2), <u>M</u>. cfr. <u>tuberculata</u> (79-127/m^2) and <u>P</u>. cfr. <u>winnelli</u> (61-91/m^2). These four species comprised 90% of the chironomids present at 25 m.

Naididae Distribution --

Naidids occurred at all depths sampled (a total of 16 species) but in reduced numbers beyond 15 m (Tables 64-70, Fig. 156). Abundance of naidids was also reduced at 3 m (24-176/m^2) compared to other depths sampled. Naidids at 6, 12 and 15 m had similar abundances (297-1085/m^2). Peak abundance of naidids was centered around the 9 m depth zone (1100-1700/m^2) where they comprised a larger proportion of the total benthic population (18%) than at any other depth. Numbers of naidids at the 20 m depth zone (109-224/m^2) were higher than numbers recorded from the 25 m depth zone (18-42/m^2).

Eight species of naidids were found at 3 m. Of these, <u>Nais elinguis</u> (55/m^2), <u>Nais variabilis</u> (18/m^2) and <u>Chaetogaster diaphanus</u>

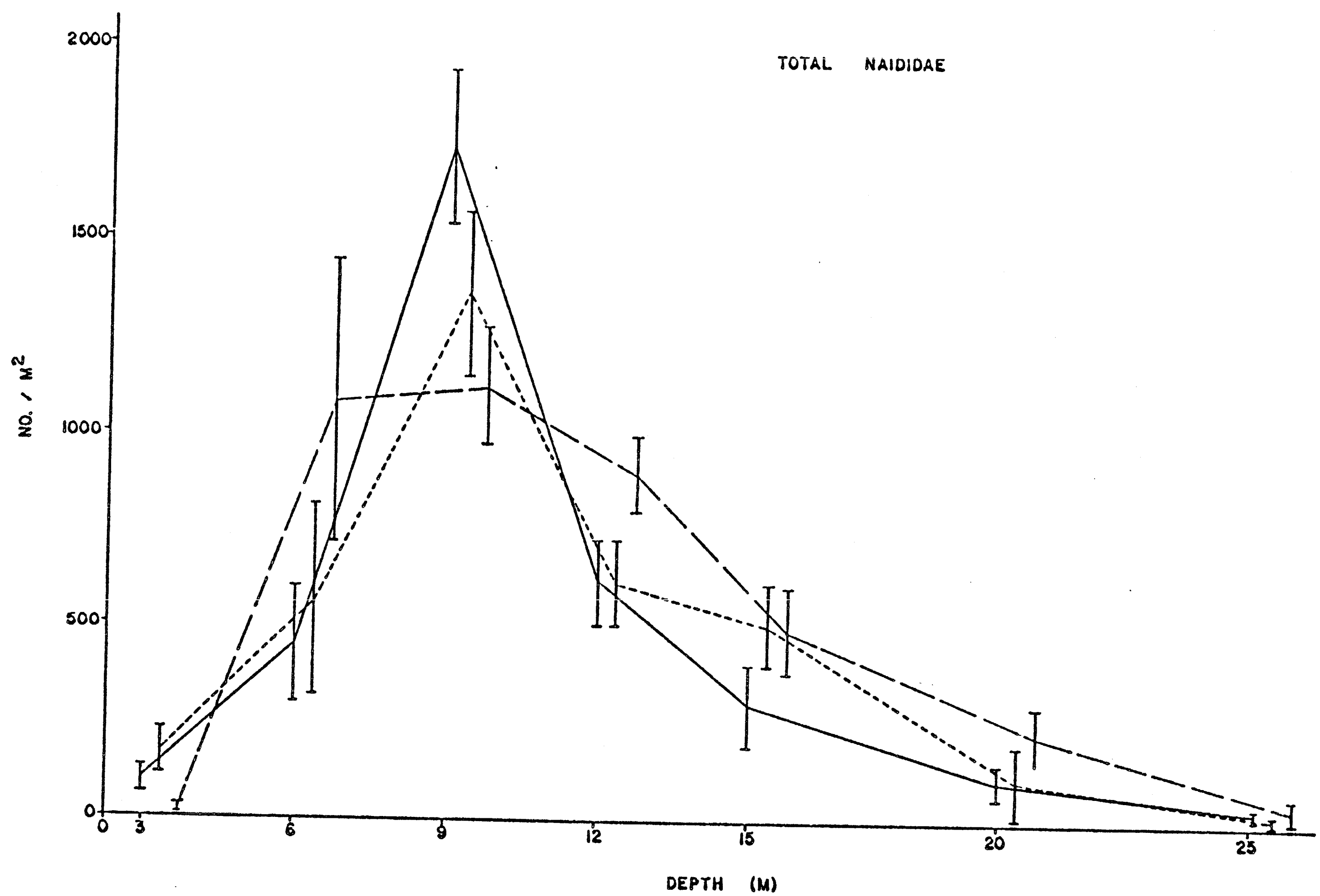


FIG. 156. Abundance of naidids in the north (———), middle (- - - -) and south (— — —) regions over depth near the J. H. Campbell Power Plant in June 1977. Standard error denoted by vertical bar.

($10/m^2$) comprised 82% of the naidid population.

At 6 m, 11 naidid species were found. The four most abundant naidids were: C. diaphanus ($277/m^2$), Piguetiella michiganensis ($123/m^2$), Uncinais uncinata ($113/m^2$) and N. variabilis ($69/m^2$). Mean abundance of naidids at 6 m was $704/m^2$.

The 9 m depth zone samples contained 12 species of naidids as well as the greatest abundance of naidids found at any depth ($1410/m^2$). The most abundant naidid species were C. diaphanus ($547/m^2$), S. lacustris ($289/m^2$), P. michiganensis ($287/m^2$) and U. uncinata ($190/m^2$).

Twelve species of naidids were found at 12 m. The dominant species were P. michiganensis ($242/m^2$), C. diaphanus ($178/m^2$), U. uncinata ($97/m^2$) and S. lacustris ($73/m^2$). Mean abundance of naidids at 12 m was ($714\ m^2$).

At 15 m there were 13 naidids species present. The most abundant naidids were: P. michiganensis ($164/m^2$), Paranais simplex ($71/m^2$), U. uncinata ($59/m^2$), Paranais litoralis ($46/m^2$) and C. diaphanus ($44/m^2$). Mean abundance of naidids at 15 m was $430/m^2$.

Of the six species of naidids present at 20 m, P. simplex ($81/m^2$) and P. litoralis ($36/m^2$) were the most common. Mean abundance of naidids was $147/m^2$.

Only four species of naidids were oberved at 25 m; P. litoralis ($16/m^2$) was the most common. Other naidids present were Vejdovskyella intermedia, P. simplex and P. michiganensis. At 25 m mean abundance of naidids was $30/m^2$.

Tubificidae Distribution --

Only ten species of tubificids were found in the survey area. The dominant form present in the tubificid population was immature without hair chaeta (im w/o hc) (57-100% of all tubificids). Tubificids were very sparse in the 3 to 6 m zones ($2/m^2$ and $28/m^2$, respectively). Tubificid species present were L. hoffmeisteri, L. profundicola and P. moldaviensis (Tables 64-70, Fig. 157).

Tubificid populations peaked at 9 m ($1056/m^2$) and 15 m ($1067/m^2$). At 9 m tubificids comprised the largest percentage of the total animals present (14%) at any depth zone. At 12, 20 and 25 m mean abundance of tubificids was $466/m^2$, $259/m^2$ and $261/m^2$, respectively.

Of the seven tubificid taxa found at 9 m, the dominant identifiable tubificid was Limnodrilus hoffmeisteri ($156/m^2$). Other taxa present in

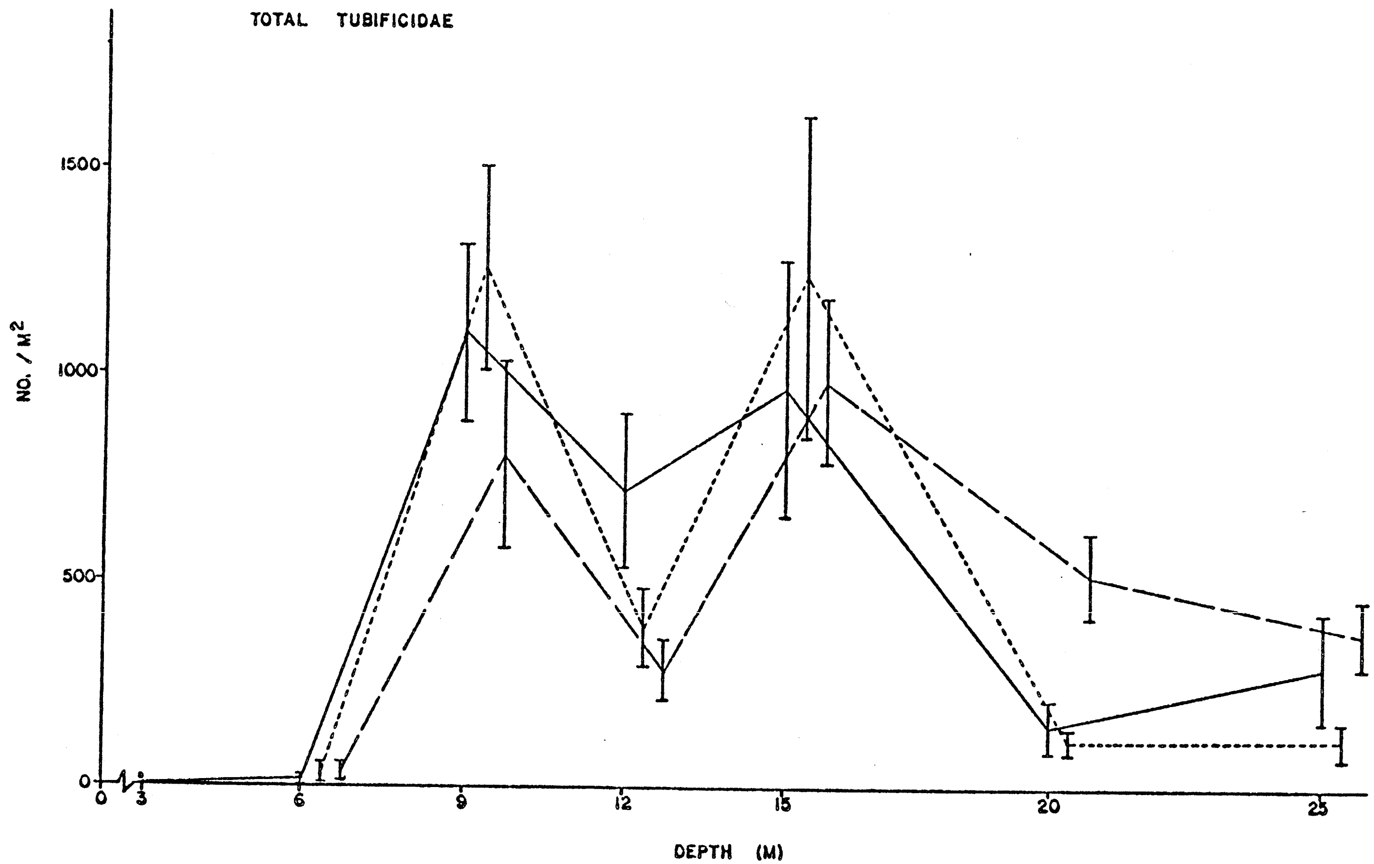


FIG. 157. Abundance of tubificids in the north (———), middle (- - - -) and south (— — —) regions near the J. H. Campbell Power Plant in June 1977. Standard error denoted by vertical bar.

moderate abundances were *Potamothrix moldaviensis* ($51/m^2$), *Limnodrilus profundicola* ($44/m^2$) and *Limnodrilus angustipenis* ($34/m^2$).

At 12 m *L. hoffmeisteri* was the most abundant tubificid species ($45/m^2$) of the seven identifiable tubificid taxa collected. Remaining species' abundances were split evenly between *L. profundicola*, *P. moldaviensis*, *Peloscolex freyi* and *L. angustipenis*.

Of the seven taxa of tubificids collected at 15 m, the most abundant were *P. moldaviensis* ($95/m^2$) and *L. hoffmeisteri* ($93/m^2$) . The only other common tubificid was *Potamothrix vejdovskyi* ($36/m^2$).

Of the seven tubificid species found at 20 m, *L. hoffmeisteri* was the most common species ($55/m^2$). *P. moldaviensis* and *P. vejdovskyi* were the only identifiable tubificids present in significant numbers at 20 m ($12/m^2$ and $18/m^2$, respectively).

Five species of tubificids were collected at 25 m . *L. hoffmeisteri* was the dominant tubificid species ($32/m^2$), followed by *P. vejdovskyi* ($10/m^2$). The immature with hair chaeta (im w/hc) comprised 17% ($44/m^2$) of the tubificids at 25 m. *Peloscolex superiorensis* ($8/m^2$) was present in its maximum abundance at 25 m.

Stylodrilus heringianus Distribution --

Distribution of *Stylodrilus heringianus* was similar across the regions (Tables 64-70, Fig. 158) but was not taken at depths shallower than 15 m except in the middle region at 9 m. At 15 m mean abundance was $933/m^2$. Population size increased approximately two-fold at 20 m ($2050/m^2$) when compared to 15 m. The number of *S. heringianus* collected continued to increase at 25 m ($2954/m^2$). Abundances of *S. heringianus* at 15, 20 and 25 m corresponded to 6%, 20% and 25% of the total animal density, respectively (Fig. 159).

Pontoporeia affinis Distribution --

Pontoporeia affinis were sorted into size classes following the procedure of Mozley (1974). Immature *P. affinis* were sorted into size classes <3 mm, 3-4.9 mm, 5-7 mm and >7 mm. Mature *P. affinis* were sorted into gravid females, spent females and males. Of particular importance to the present study was the <3 mm size group which was considered to be young *P. affinis* released from the marsupium of females earlier in the season (presumably in April and/or May).

It has also come to the author's attention that the species name for *P. affinis* has been changed to *P. hoyi* during the course of the study (Segerstrale 1977). Since all tables and figures had already been

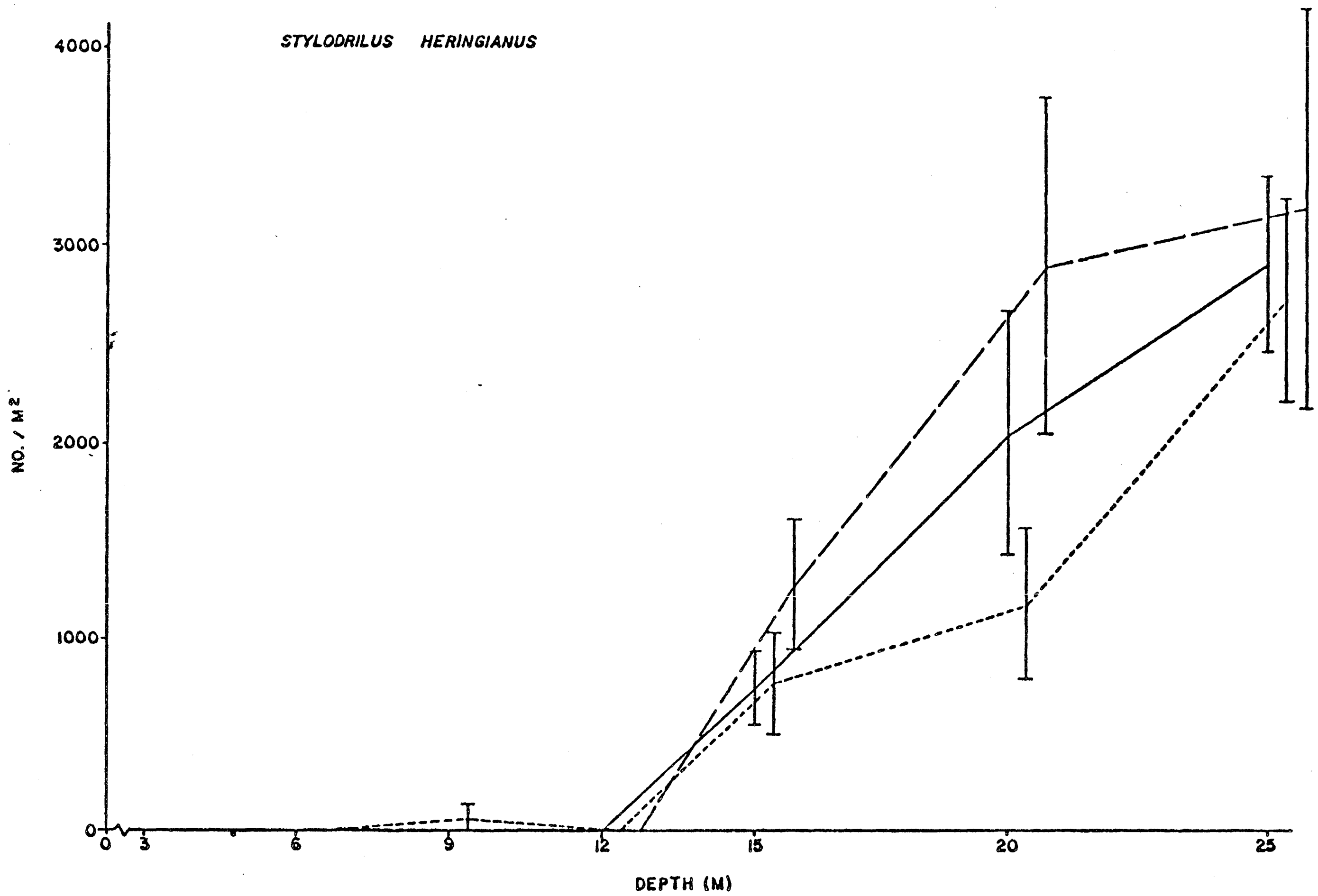


FIG. 158. Abundance of S. heringianus in the north (———), middle (- - - -) and south (— — —) regions near the J. H. Campbell Power Plant in June 1977. Standard error denoted by vertical bar.

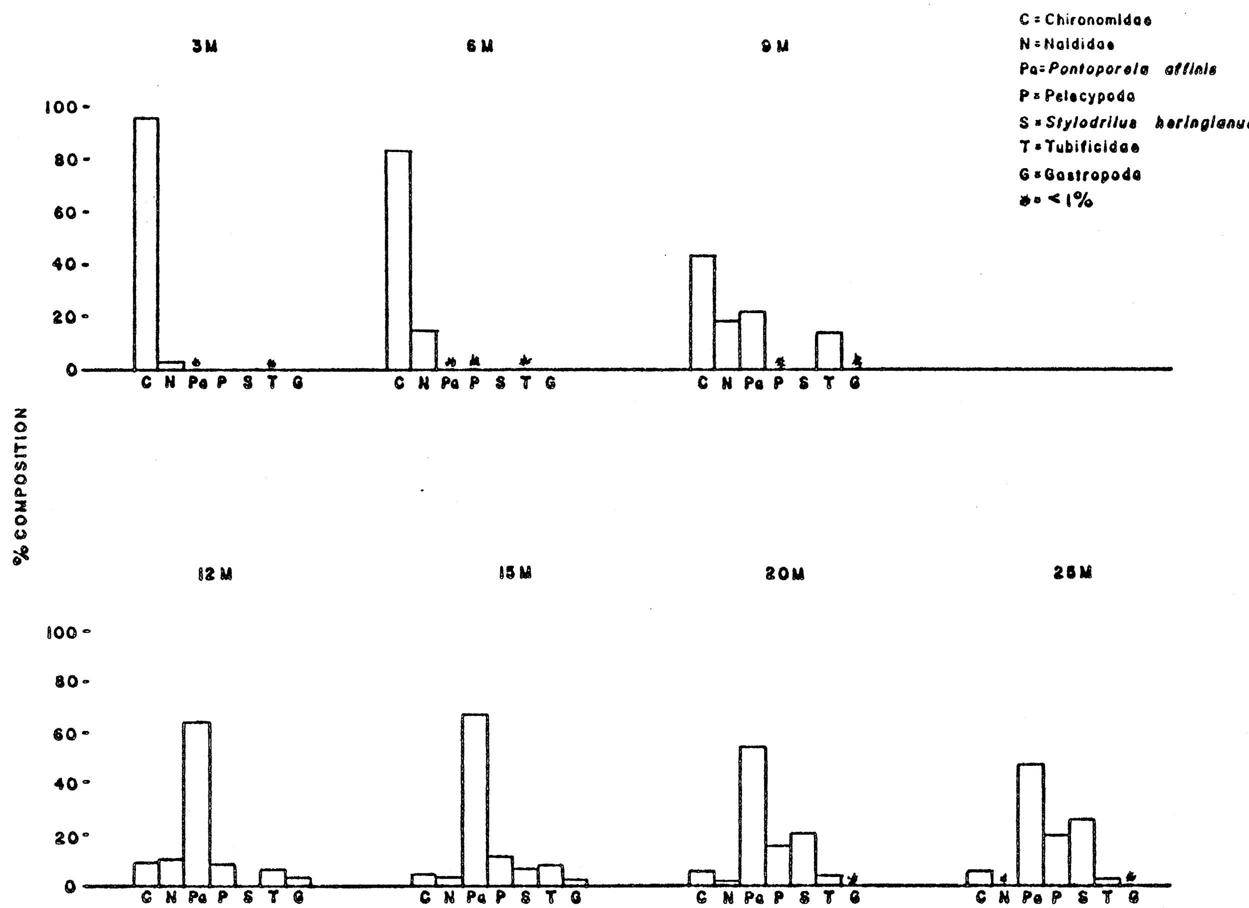


FIG. 159. Percent composition of major taxonomic groups near the J. H. Campbell in June 1977.

completed, it was decided to retain the old name, P. affinis.

The general pattern of distribution of P. affinis was similar in all three regions (Tables 64-70, Fig. 160). At 3 and 6 m there were very low number of P. affinis present ($4/m^2$ and $38/m^2$, respectively). Of these 86% were young (<3 mm).

The first depth zone where P. affinis began to occur in significant numbers was at 9 m ($1733/m^2$). Young individuals (<3 mm) dominated the population (96%) of P. affinis.

The trend of increasing abundances of P. affinis with depth was also evident at 12 m. Size of the population increased about 2.5 times when compared with 9 m levels and comprised 64% of all the animals present at 12 m. Average density present was $4822/m^2$ with most (99.7%) being young P. affinis.

Peak abundance of P. affinis occurred at 15 m ($10,023/m^2$) in all regions, which was approximately a two-fold increase in the population size when compared with 12 m levels. P. affinis comprised 67% of the total animal population at 15 m. Again young P. affinis was the most numerous size class (98%).

At 20 m population size began to decline and the population age composition began to shift to slightly older individuals. Mean abundance of P. affinis at 20 m was $5454/m^2$. Although young individuals were still the dominant size class (73%), age structure of the P. affinis population at 20 m included more 3-4.9 mm (13%) and 5-7 mm (13%) individuals than was found at shallower depths.

Although the average number of P. affinis at 25 m ($5457/m^2$) was similar to that observed at 20 m, the population age structure shifted to older individuals. At 25 m 57% of the P. affinis population was comprised of the youngest size class. The 3-4.9 mm and 5-7 mm classes comprised 20% and 23% of the P. affinis population, respectively.

Gastropoda Distribution --

Gastropods were represented by three taxa; Valvata sincera, Amnicola sp. and Lymnaea sp. Possibly, a fourth taxa, Somatogyrus sp., was present but since it is rare in the lake and taxonomic determination is difficult, it has not been included. At all depths the most numerous gastropod was V. sincera. Lymnaea sp. was limited to a single occurrence at 25 m in the middle region.

The general distributional pattern of gastropods was different from region to region (Tables 64-70, Fig. 161). Numbers of gastropods in the

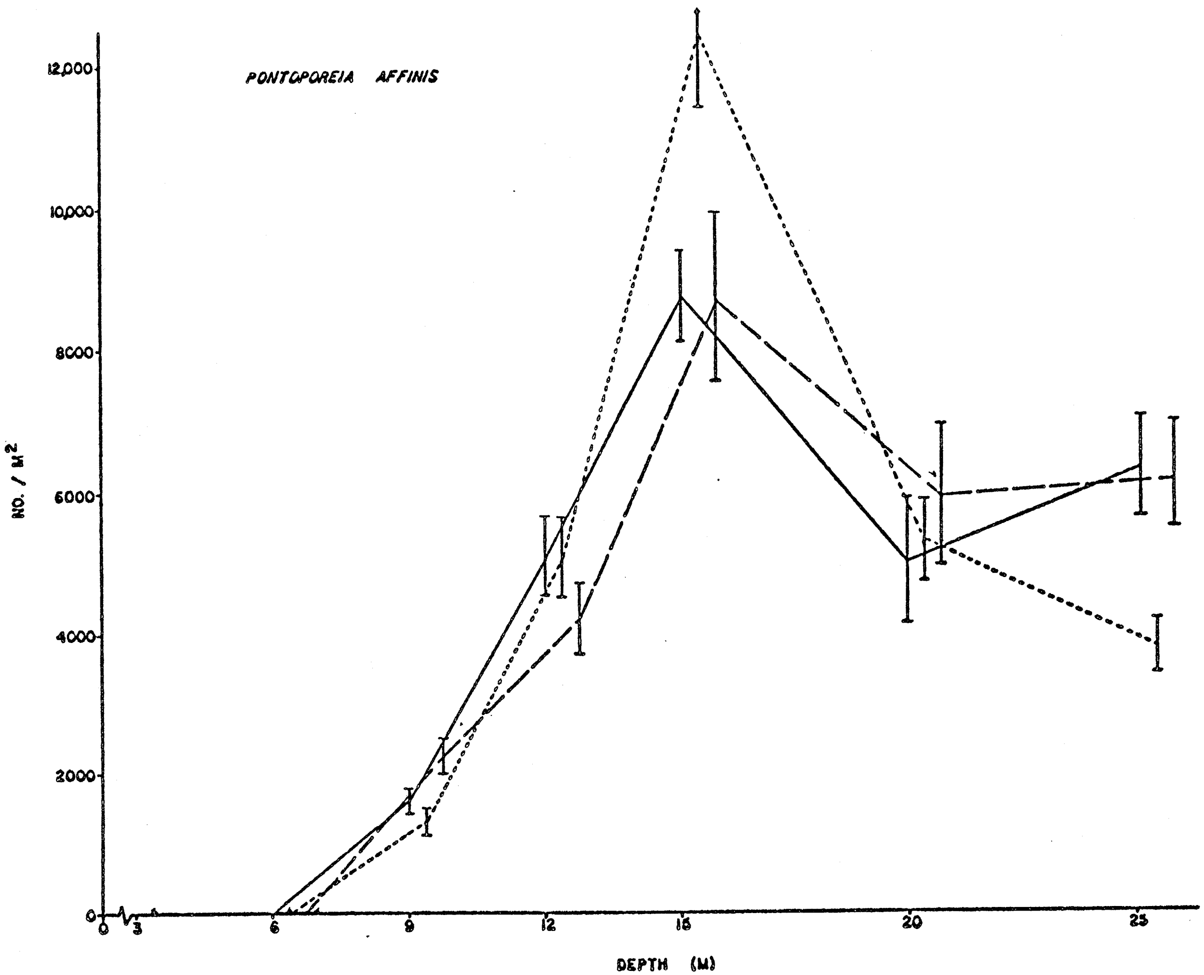


FIG. 160. Abundance of P. affinis in the north (———), middle (- - - -) and south (— — —) regions near the J. H. Campbell Power Plant in June 1977. Standard error denoted by vertical bar.

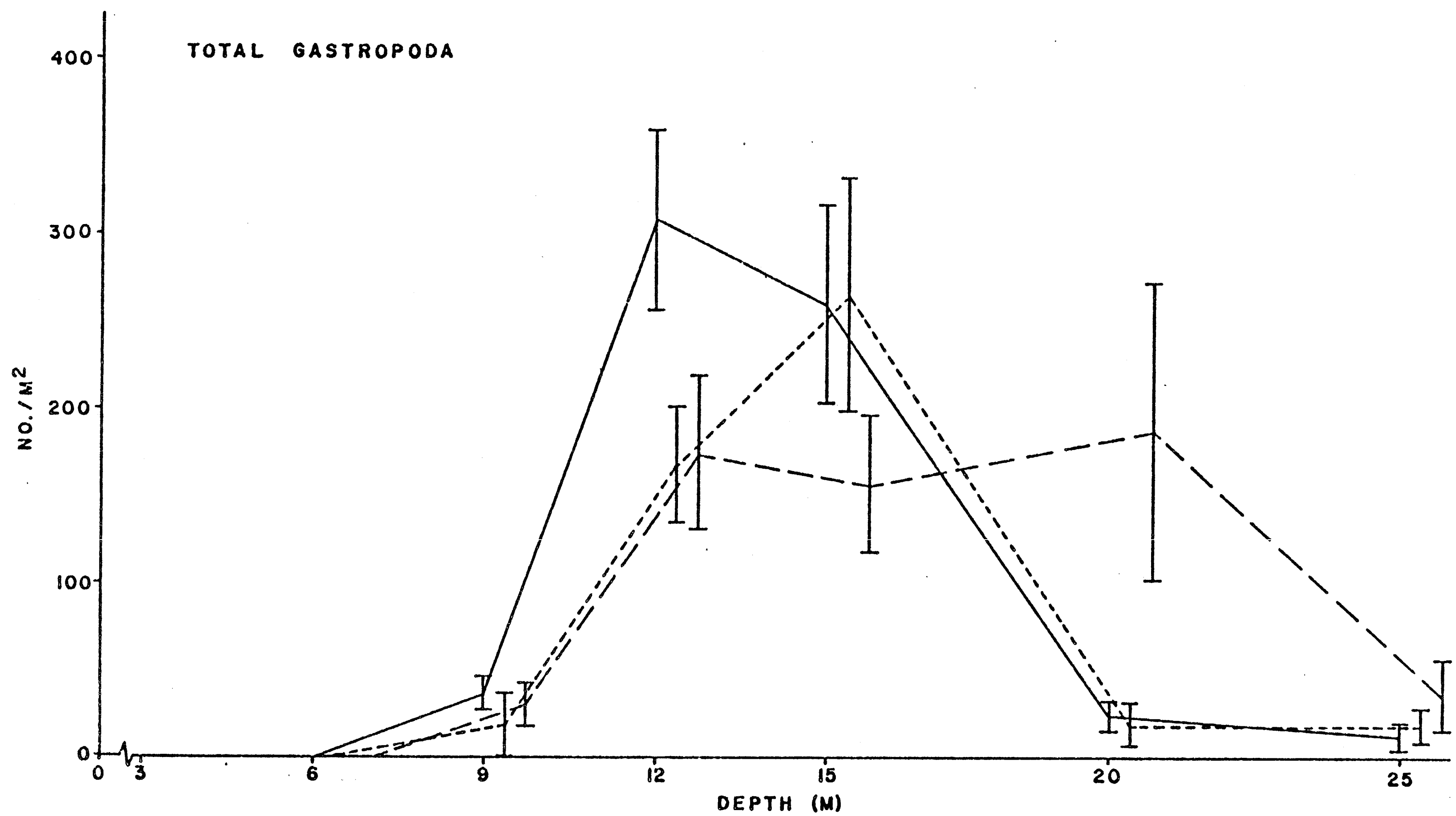


FIG. 161. Abundance of gastropods in the north (———), middle (- - - -) and south (— — — —) regions near the J. H. Campbell Power Plant in June 1977. Standard error denoted by vertical bar.

north region peaked at 12 m ($309/m^2$) and declined sharply at 20 m ($24/m^2$). Numbers of gastropods in the middle region peaked at 15 m ($267/m^2$) and declined sharply at 20 m ($18/m^2$). However, distribution of gastropods in the south region was different in that there was generally a lower ($175/m^2$) but more even abundance in the 12-20 m depth zones which was followed by a decline at 25 m ($36/m^2$).

Gastropods were not found in the 3 and 6 m depth zones. Depth of maximum abundance was 12-15 m ($218-228/m^2$). At 12-15 m V. sincera comprised 82-84% and Amnicola sp. 16-18% of the gastropods collected. Gastropods at the depth of maximum abundance amounted to only 2-4% of the total animals present (Table 71). With the exception of the south region at 20 m, the depth zones 9, 20 and 25 m had similar gastropod abundances ($20-40/m^2$). In the south region at 20 m average abundance was higher ($188/m^2$).

Pelecypoda Distribution --

Pelecypod distribution patterns were dissimilar among regions (Tables 64-70, Fig. 162). Few pisidia were taken at depths less than 12 m. In the north region there appeared to be a plateau in numbers of pelecypods collected, which was reached at 15-20 m followed by an increase at 25 m. In the middle region there was a more sudden decrease in numbers of pelecypods proceeding from 15 m to 20 m. Numbers remained low at 25 m. In the south region numbers of pelecypods maintained a steadily increasing abundance with increasing depth throughout the observed depth zones.

Pelecypods were represented by 2 genera [Pisidium (15 species) and Sphaerium (3 species)], Pisidium was the most abundant pelecypod genus. Pisidium ranged from 93% of all pelecypods at 20 m to 99% at 12 m. At 3-6 m pelecypod abundance was very low, being comprised entirely of Pisidium ($0-2/m^2$). Pelecypod abundance from 9-25 m ranged from 1-19% of the total animal population. P. fallax, P. casertanum and P. nitidum were the most abundant pelecypods at 9-12 m ($8-210/m^2$). The latter two species were the most numerous Pisidium species at 15 m ($663/m^2$ and $309/m^2$, respectively). P. conventus ($366-586/m^2$) and P. nitidum ($358-576/m^2$) were the dominant species of Pisidium at 20-25 m. P. nitidum was the most consistently occurring taxa of Pisidium ranging from 11-27% of the Pisidium species present in the depth range 9-25 m. P. casertanum, P. nitidum and P. conventus were the three most numerous when averaged over all samples ($277/m^2$, $275/m^2$ and $218/m^2$ respectively). Most unidentified pisidia occurred at 25 m and may have been young P. conventus.

The second genus of pelecypods, Sphaerium, was represented by: S. transversum, S. nitidum and S. striatinum. Of all Sphaerium, only S. striatinum occurred shallower than 15 m. All three species were most

TABLE 71. Percent composition of major taxonomic groups in each depth zone near the J. H. Campbell Plant in June 1977.

Region	Chironomidae	Naididae	Tubificidae	*S. heringianus*	*P. affinis*	Pelecypoda	Gastropoda
North - 3 m	96.85	2.97	0.17	0	0	0	0
Middle- 3 m	93.75	5.49	0	0	0.38	0	0
South - 3 m	99.07	0.93	0	0	0	0	0
Total - 3 m	96.41	3.26	0.07	0	0.13	0	0
North - 6 m	90.26	9.01	0.12	0	0	0.12	0
Middle- 6 m	81.12	15.44	0.99	0	2.13	0	0
South - 6 m	76.35	21.94	0.74	0	0.74	0.12	0
Total - 6 m	82.76	15.42	0.62	0	0.84	0.04	0
North - 9 m	39.58	23.09	14.64	0	21.40	0.56	0.48
Middle- 9 m	50.33	16.70	15.44	0	16.11	0.97	0.22
South - 9 m	42.83	14.81	10.59	0	29.86	1.43	0.40
Total - 9 m	43.21	18.13	13.61	0	22.32	0.99	0.36
North - 12 m	8.23	7.30	8.52	0	60.56	11.45	3.65
Middle- 12 m	7.33	8.43	5.32	0	69.57	6.97	2.29
South - 12 m	10.73	13.44	4.24	0	62.94	5.41	2.61
Total - 12 m	8.68	9.50	6.20	0	64.21	8.19	2.90
North - 15 m	3.11	2.10	7.32	5.63	66.24	13.08	1.97
Middle- 15 m	2.68	2.85	6.95	4.31	70.49	10.99	1.49
South - 15 m	5.56	3.57	7.19	9.36	63.37	9.36	1.15
Total - 15 m	3.69	2.84	7.14	6.24	67.06	11.11	1.53
North - 20 m	5.94	1.18	1.57	22.21	54.47	13.91	0.26
Middle- 20 m	5.22	1.34	1.42	14.55	65.82	10.90	0.22
South - 20 m	4.65	1.76	4.03	22.78	46.70	17.89	1.47
Total - 20 m	4.74	1.47	2.57	20.39	54.24	14.79	0.76
North - 25 m	5.26	0.23	2.22	22.21	48.45	21.28	0.09
Middle- 25 m	4.85	0.22	1.37	32.81	45.59	14.11	0.22
South - 25 m	4.98	0.32	2.80	23.88	46.22	21.44	0.27
Total - 25 m	5.05	0.26	2.24	25.40	46.91	19.15	0.19

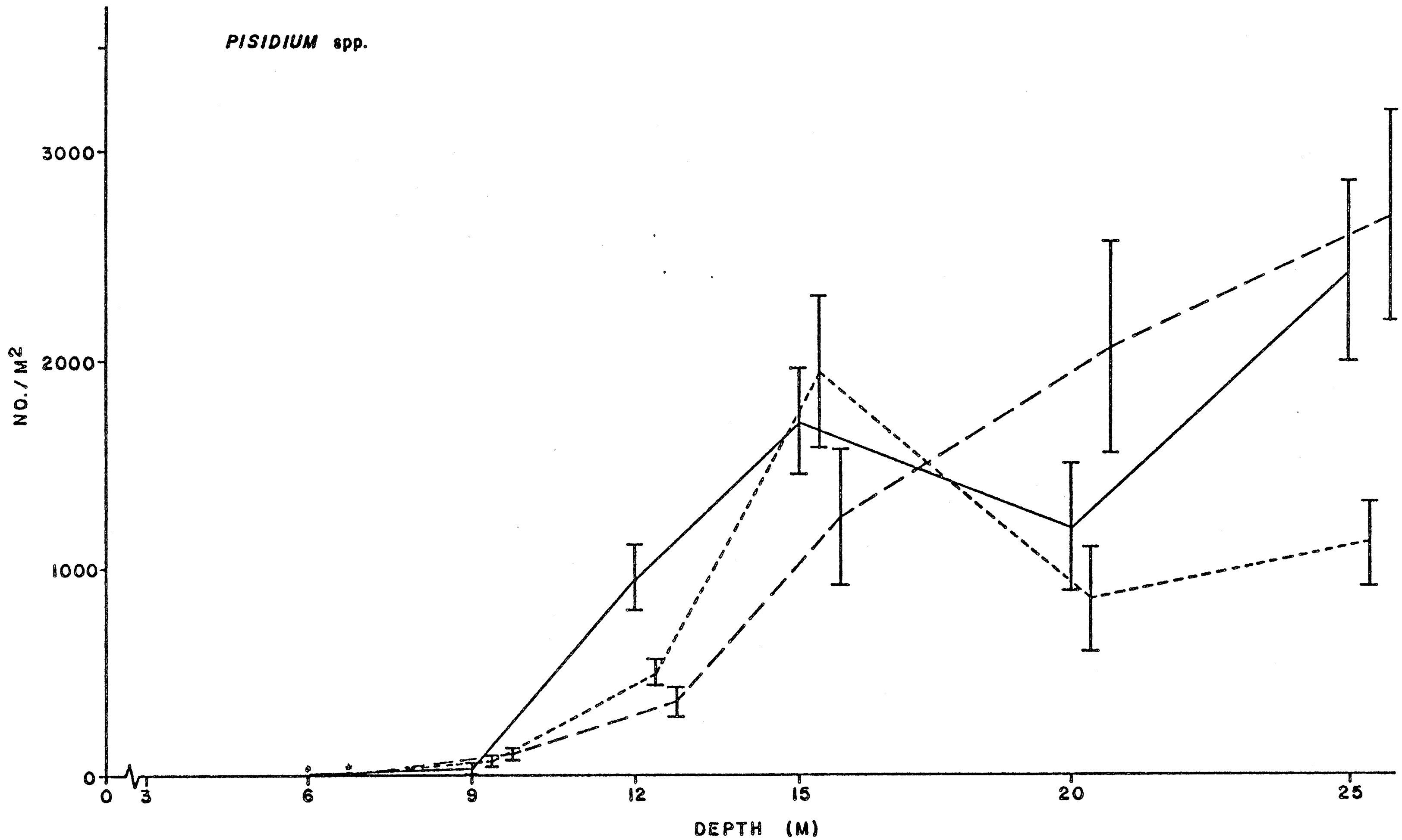


FIG. 162. Abundance of the most numerous pelecypod, Pisidium spp., in the north (———), middle (- - - - - -) and south (— — —) regions near the J. H. Campbell Power Plant in June 1977. Standard error denoted by vertical bar.

abundant in deeper water. *S. transversum* was rare; only seven individuals (five of those from the south region at 15 m) were found. *S. nitidum* was the most abundant of the three taxa (87-105/m^2). Similar to *S. nitidum*, *S. striatinum* was most abundant in the 20-25 m depth zones (24-42/m^2).

Lake Michigan - Statistical Analysis

Replicability and Reliability --

Based on June 1977 data and using total number of animals per grab, the within mean square from a two-way analysis of variance (Depth x Region) was used in conjunction with Sokal and Rohlf's (1969) formulas to estimate the least detectable true difference (δ) and reliability of the data for detecting changes in benthos near the Campbell Plant. The theoretical relationship between δ and the successive number of grabs (n) needed to alter δ is presented in Fig. 163. While any n from Fig. 163 could be chosen, six replicates were selected for use in calculating δ based on the relationship between s^2 (variance) and the succcessive number of grabs presented in Fig. 164. For any particular depth zone the extreme values for variance began to approach a stable level at approximately six replicates. When six replicates were related to the δ value (Fig. 163), δ equalled 143 animals per sample location ($\alpha = 0.05$, $P = 0.95$). Due to the large variances associated with these natural populations of animals (Coefficient of Variation = 40%), the difference between any two sample location means must differ by 143 animals in order to detect a significant difference at $\alpha = 0.05$ and $P = 0.95$.

The effect of increasing sampling effort was negligible when evaluated against time and cost factors. By doubling effort to 12 replicates per location, the ability to detect change (δ) was increased 36% to 92 animals per location. By tripling the effort to 18 replicates per location, the ability to detect change (δ) was increased 50% to 72 animals per location. Therefore, based on the June 1977 data set, future sampling efforts in the vicinity of the J.H. Campbell Plant should have six replicates per sample location ($\alpha = 0.05$ and $P = 0.95$) if a detectable difference of 143 animals between any two sample locations is acceptable. If increased sensitivity is required sample effort will need to be substantially increased.

Analyses of Variance --

Results of tests for normality of subsets of the benthos data set are presented in Table 72. The following transformations were used in order to normalize specific data sets for subsequent application of parametric statistics : total animals (3-25 m) ($\sqrt{x}$), shallow-zone chironomids (3-9 m) (log [x+1]), deep-zone chironomids (12-12 m) (none),

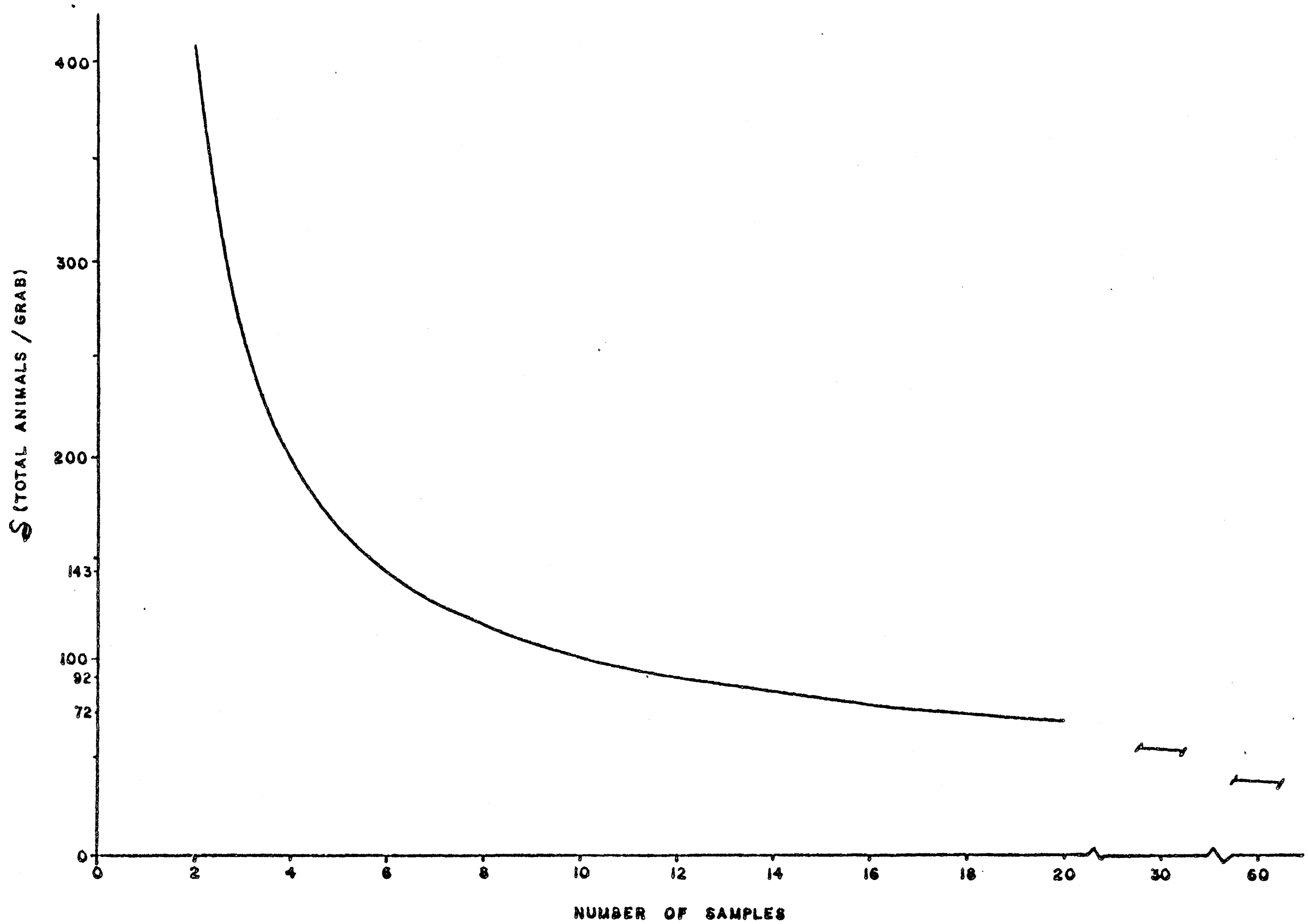


FIG. 163. . Theoretical relationship between the least detectable true difference (δ) and number of samples (n) for total animals per grab from 210 samples taken in June 1977 near the Campbell Plant (α = 0.05, P = .95).

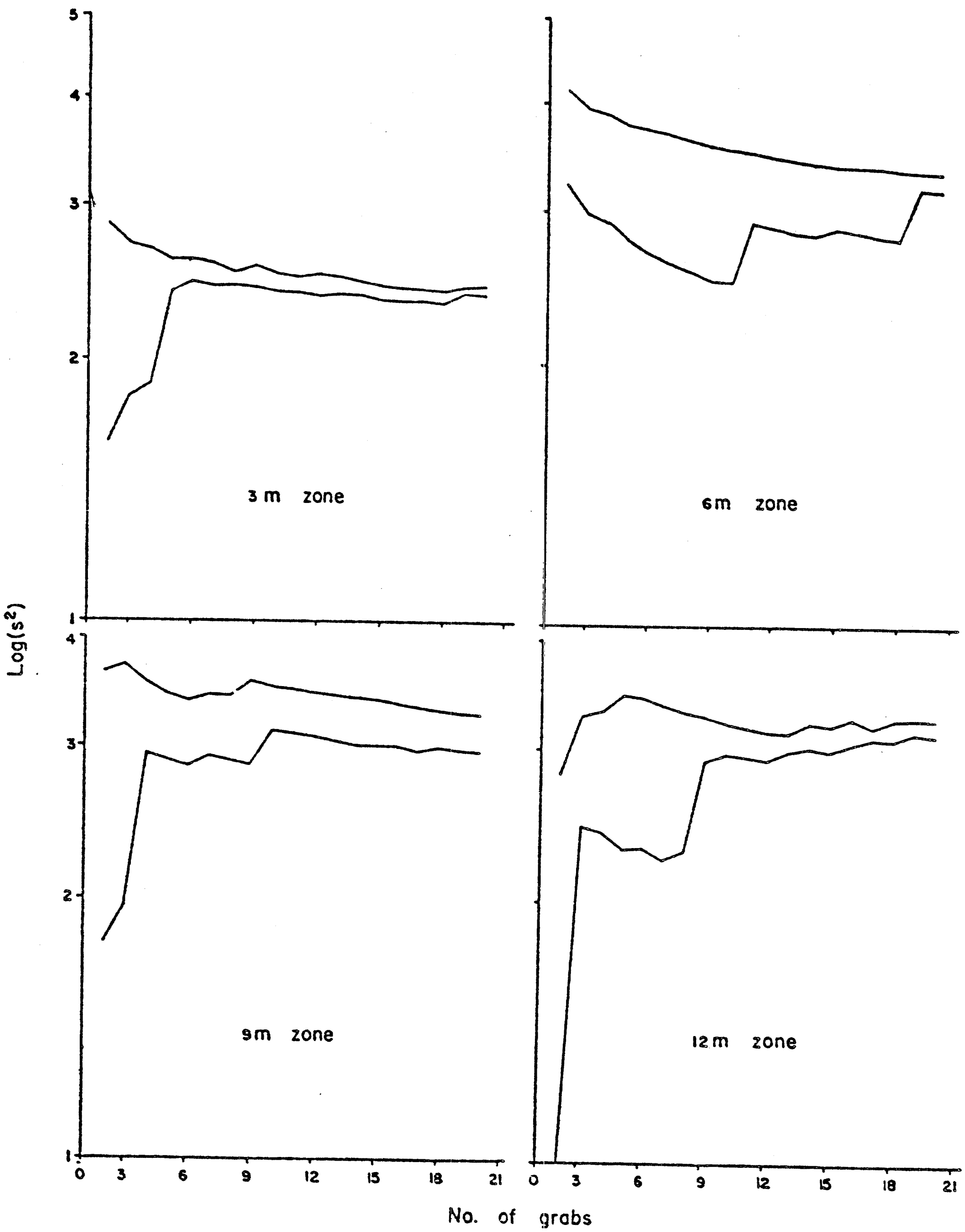


FIG. 164 . The relationship between the variance (s^2) and number of replicates. The two lines on each graph outline the upper and lower extremes of five curves generated for each depth zone from random draws from 30 replicates at each depth zone.

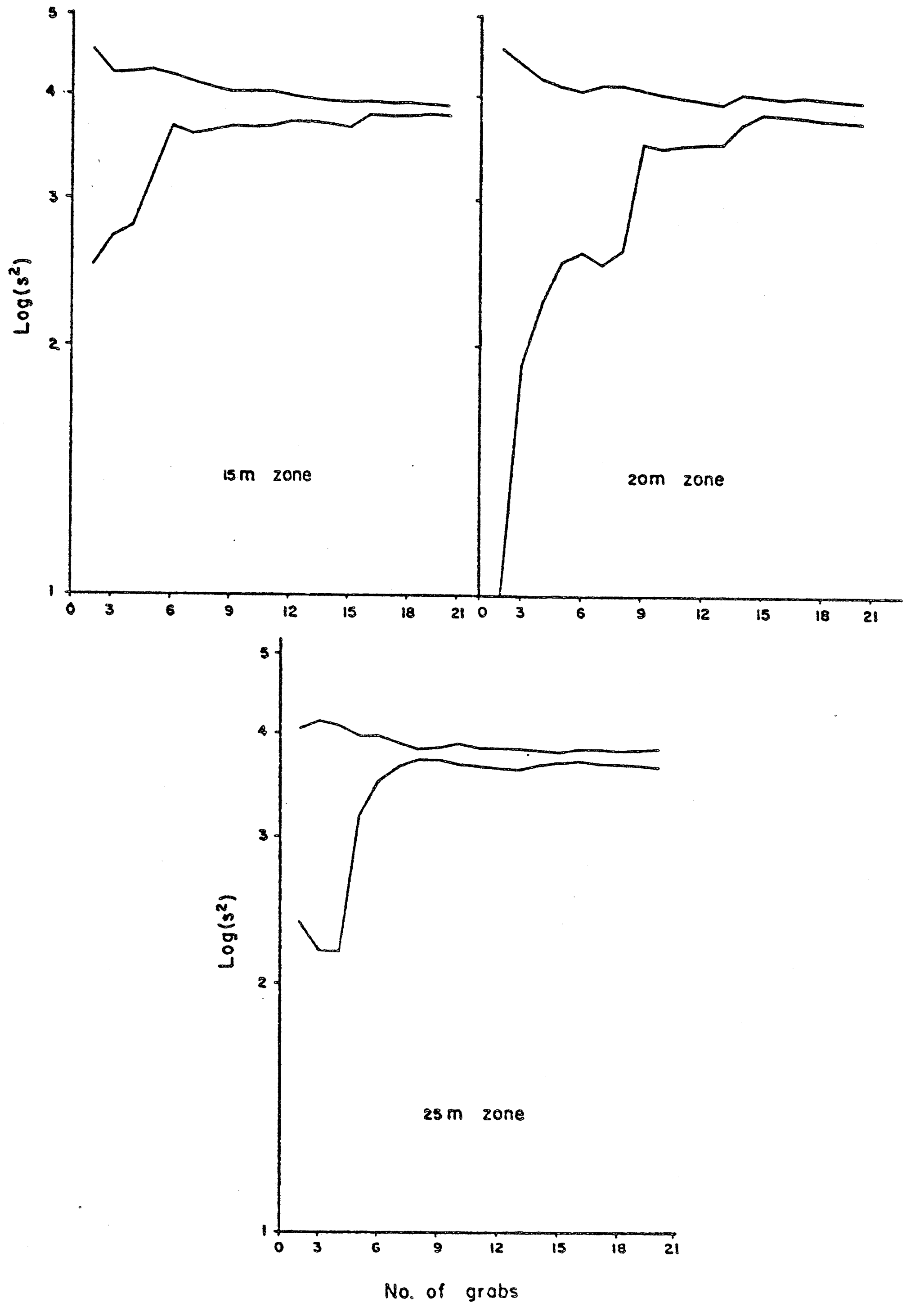


FIG. 164. (continued).

TABLE 72. Results of testing for normality of data subsets from June 1977 in the vicinity of the J. H. Campbell Power Plant (n = number of samples, Maxdiff = maximum cumulative frequency distribution difference, L = Lilliefor's 99% quartile test value), * = significant.

		n	MAXDIFF	L	SIGNIFICANCE	SKEWNESS	KURTOSIS	DATA SET USED IN ANOVA
T. Animals								
3-25 m	No Trans	210	0.117	0.071	NS	0.858	-0.023	
	Log (x+1)	210	0.074	0.071	NS	-0.287	-0.651	
	√x	210	0.056	0.071	*	0.310	-0.669	X
P. affinis								
9-25 m	No Trans	150	0.102	0.084	NS	0.967	1.110	
	Log (x+1)	150	0.096	0.084	NS	-0.508	-0.285	
	√x	150	0.076	0.084	*	0.217	-0.495	X
T. Chir.								
3-25 m	No Trans	210	0.219	0.071	NS	1.645	3.214	
	Log (x+1)	210	0.114	0.071	NS	0.106	-0.959	
	√x	210	0.167	0.071	NS	0.773	-0.209	
T. Chir.								
3-9 m	No Trans	90	0.108	0.109	*	1.518	3.369	
	Log (x+1)	90	0.056	0.109	*	-0.053	0.269	X
	√x	90	0.078	0.109	*	0.703	0.924	
T. Chir.								
12-25 m	No Trans	120	0.101	0.094	NS	0.609	0.636	X
	Log (x+1)	120	0.160	0.094	NS	-0.715	0.450	
	√x	120	0.119	0.094	NS	-0.141	-0.033	
Pisidium								
12-25 m	No Trans	120	0.177	0.094	NS	1.038	0.188	
	Log (x+1)	120	0.070	0.094	*	-0.481	0.017	X
	√x	120	0.108	0.094	NS	0.348	-0.646	
S. heringianus								
15-25 m	No Trans	90	0.128	0.109	NS	1.047	0.402	
	Log (x+1)	90	0.137	0.109	NS	-0.858	0.109	
	√x	90	0.070	0.109	*	0.088	-0.633	X
Naididae								
3-15 m	No Trans	150	0.160	0.084	NS	1.694	3.700	
	Log (x+1)	150	0.087	0.084	NS	-0.296	-0.707	
	√x	150	0.072	0.084	*	0.366	-0.187	X
Tubificidae								
9-15 m	No Trans	90	0.143	0.109	NS	1.611	3.102	
	Log (x+1)	90	0.106	0.109	*	-0.579	-0.177	
	√x	90	0.052	0.109	*	0.289	0.033	X

naidids ($\sqrt{x}$), _Pontoporeia affinis_ (9-25 m) ($\sqrt{x}$), tubificids (9-15 m) ($\sqrt{x}$), _Pisidium_ spp. (12-25 m) (log [x+1]) and _Stylodrilus heringianus_ (15-25 m) ($\sqrt{x}$). No transformation of the "total chironomids" data set (3-25 m) would normalize it. Data subsets were chosen for each group based on depth zones of maximum occurrence.

An Analysis of Variance (ANOVA) was performed on each of the above transformed data sets (Tables 73-81). For the total animals, _P. affinis_ and naidid data sets there were no overall regional differences, but there were significant depth and interaction effects. For the deep-zone chironomid data set only regional effects were significant. Only depth effects were found for the tubificid and _S. heringianus_ data sets. The shallow-zone chironomid data set had no overall significant regional, depth or interaction effects. The _Pisidium_ spp. data set had significant overall effects for regions, depths and interaction terms.

Student-Neuman-Keuls Multiple Comparisons --

The within mean square from the appropriate ANOVA for each major taxonomic group was used in conjunction with the Student-Neuman-Keuls multiple comparison technique. In the first portion of this section (see below) results from comparisons made within a specific depth zone across regions for dominant taxonomic forms are presented (Fig. 165). In the second portion results from comparisons made within a specific region across depth zones in that region for dominant taxonomic forms are presented (Fig. 166).

Multiple comparisons among regions within depth zones --

The 3 m depth zone -- There were two major taxonomic groups dominant at 3 m; the chironomids and the naidids (Tables 64-70, Fig. 165). There were no significant differences across regions for the chironomids. However, naidids in the south region were significantly less abundant ($24/m^2$) than those in the middle ($176/m^2$) and north ($103/m^2$) regions. The dominant naidid in the middle and north regions was _Nais elinguis_. _N. elinguis_ did not occur at 3 m in the south region.

The 6 m depth zone -- At 6 m average number of animals in the north region ($5042/m^2$) was significantly higher than average numbers observed in the middle region ($3691/m^2$) (Tables 64-70, Fig. 165). Average number of animals in the south region ($4945/m^2$) was not different from either region. Dominant taxonomic groups were chironomids and naidids (Table 71). Chironomids were significantly more abundant in the north ($1388/m^2$) and south ($1206/m^2$) regions when compared to the middle region ($957/m^2$). _Chironomus_ sp. was ~$300/m^2$ less abundant in the middle than in the north and south regions. _R._ cfr. _demeijerei_ was ~$1600/m^2$ more abundant in the north and ~$500/m^2$ more abundant in the south than in the

TABLE 73. Analysis of variance for total animals (3-25 m) using the $\sqrt{x}$ transformation. The correction factor used was 0.995. NS = not significant, alpha = 0.05, * = significant.

SOURCE	CORRECTED DEGREES OF FREEDOM	CORRECTED MEAN SQUARE	F	SIGNIFICANCE
REGION	2	4.07	0.78	NS
DEPTH	6	253.36	48.35	*
REGION x DEPTH	12	12.32	2.35	*
WITHIN CELL	188	5.24		

TABLE 74. Analysis of variance for total animals (3-25 m) using no transformation. The correction factor used was 0.995.

SOURCE	CORRECTED DEGREES OF FREEDOM	CORRECTED MEAN SQUARE
REGION	2	2552.23
DEPTH	6	135559.22
REGION x DEPTH	12	9474.50
WITHIN CELL	188	3220.63

TABLE 75. Analysis of variance for shallow-zone chironomids (3-9 m) using the log (x+1) transformation. The correction factor used was 0.989. NS = not significant, alpha = 0.05.

SOURCE	CORRECTED DEGREES OF FREEDOM	CORRECTED MEAN SQUARE	F	SIGNIFICANCE
REGION	2	0.017	0.46	NS
DEPTH	2	0.030	0.80	NS
REGION x DEPTH	4	0.085	2.27	NS
WITHIN CELL	80	0.037		

TABLE 76 . Analysis of variance for naidids (3-15 m) using the $\sqrt{x}$ transformation. The correction factor used was 0.993. NS = not significant, alpha = 0.05, * = significant.

SOURCE	CORRECTED DEGREES OF FREEDOM	CORRECTED MEAN SQUARE	F	SIGNIFICANCE
REGION	2	0.56	0.66	NS
DEPTH	4	53.69	45.40	*
REGION x DEPTH	8	3.87	3.27	*
WITHIN CELL	134	1.18		

TABLE 77. Analysis of variance for tubificids (9-15 m) using the $\sqrt{x}$ transformation. The correction factor used was 0.989. NS = not significant, alpha = 0.05, * = significant.

SOURCE	CORRECTED DEGREES OF FREEDOM	CORRECTED MEAN SQUARE	F	SIGNIFICANCE
REGION	2	3.82	1.60	NS
DEPTH	2	20.02	8.38	*
REGION x DEPTH	4	1.81	0.76	NS
WITHIN CELL	80	2.39		

TABLE 78. Analysis of variance for _P. affinis_ (9-25 m) using the $\sqrt{x}$ transformation. The correction factor used was 0.993. NS = not significant, alpha = 0.05, * = significant.

SOURCE	CORRECTED DEGREES OF FREEDOM	CORRECTED MEAN SQUARE	F	SIGNIFICANCE
REGION	2	0.11	0.03	NS
DEPTH	4	205.91	60.03	*
REGION x DEPTH	8	11.34	3.31	*
WITHIN CELL	134	3.43		

TABLE 79. Analysis of variance for *Pisidium* spp. (12-25 m) using the log (x+1) transformation. The correction factor used was 0.991. NS = not significant, alpha = 0.05, * = significant.

SOURCE	CORRECTED DEGREES OF FREEDOM	CORRECTED MEAN SQUARE	F	SIGNIFICANCE
REGION	2	0.353	3.39	*
DEPTH	3	1.380	13.26	*
REGION x DEPTH	6	0.322	3.10	*
WITHIN CELL	107	0.104		

TABLE 80. Analysis of variance for deep-zone chironomids (12-25 m) using no transformation. The correction factor used was 0.991. NS = not significant, alpha = 0.05, * = significant.

SOURCE	CORRECTED DEGREES FREEDOM	CORRECTED MEAN SQUARE	F	SIGNIFICANCE
REGION	2	132.55	7.35	*
DEPTH	3	25.46	1.41	NS
REGION x DEPTH	6	23.43	1.30	NS
WITHIN CELL	107	18.03		

TABLE 81. Analysis of variance for *S. heringianus* (15-25 m) using the $\sqrt{x}$ transformation. The correction factor used was 0.989. NS = not significant, alpha = 0.05, * = significant.

SOURCE	CORRECTED DEGREES OF FREEDOM	CORRECTED MEAN SQUARE	F	SIGNIFICANCE
REGION	2	13.93	2.74	NS
DEPTH	2	87.61	17.23	*
REGION x DEPTH	4	2.27	0.45	NS
WITHIN CELL	80	5.08		

Depth Zone : 3 M

Total Animals	N 7.47	M 7.17	S 6.53	LSR = 1.38
Shallow Chironomidae	N 1.73	M 1.68	S 1.63	LSR = 0.12
Total Naididae	M 1.63	N 1.05	S 0.34	LSR = 0.66

Depth Zone: 6M

Total Animals	N 8.81	S 8.76	M 7.40	LSR = 1.38
Shallow Chironomidae	N 1.83	S 1.77	M 1.63	LSR = 0.12
Total Naididae	S 3.83	M 2.61	N 2.45	LSR = 0.66

FIG. 165.. Results of multiple comparisons of specific depth zones across region (N=north, M=middle, S=south) using the Student-Neuman-Keuls technique for the most abundant major taxonomic groups near the J. H. Campbell Power Plant in June 1977. LSR - least significant range at α = 0.05.

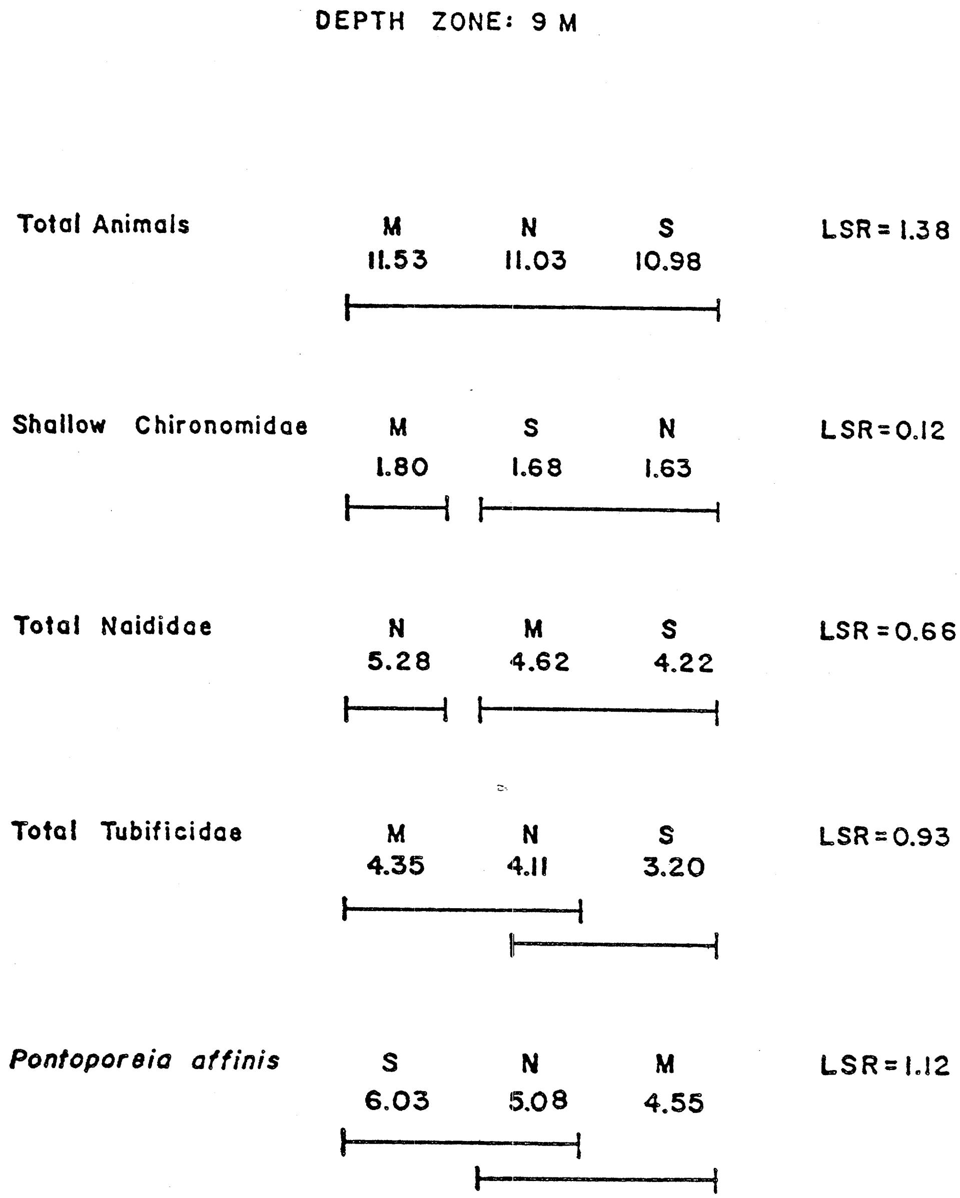


FIG. 165. (continued).

DEPTH ZONE: 12 M

Total Animals	N 11.64	M 10.91	S 10.44	LSR = 1.38
Total Tubificidae	N 3.07	M 2.30	S 1.93	LSR = 0.93
Deep Chironomidae	S 11.90	N 11.50	M 8.90	LSR = 2.57
Pontoporeia affinis	N 9.07	M 9.05	S 8.22	LSR = 1.12
Pisidium spp.	N 1.17	M 0.95	S 0.79	LSR = 0.19
Total Naididae	S 3.81	N 3.09	M 3.08	LSR = 0.66

FIG. 165. (continued).

DEPTH ZONE: 15 M

Total Animals	M 17.08	N 14.69	S 14.65	LSR = 1.38
Total Tubificidae	M 4.07	S 3.77	N 3.64	LSR = 0.93
Deep Chironomidae	S 12.60	M 7.90	N 6.80	LSR = 2.57
Pontoporeia affinis	M 14.29	N 11.96	S 11.65	LSR = 1.12
Pisidium spp.	M 1.44	N 1.42	S 1.12	LSR = 0.19
Stylodrilus heringianus	S 4.13	N 3.10	M 2.85	LSR = 1.36
Total Naididae	M 2.75	S 2.65	N 2.00	LSR = 0.66

FIG. 165. (continued).

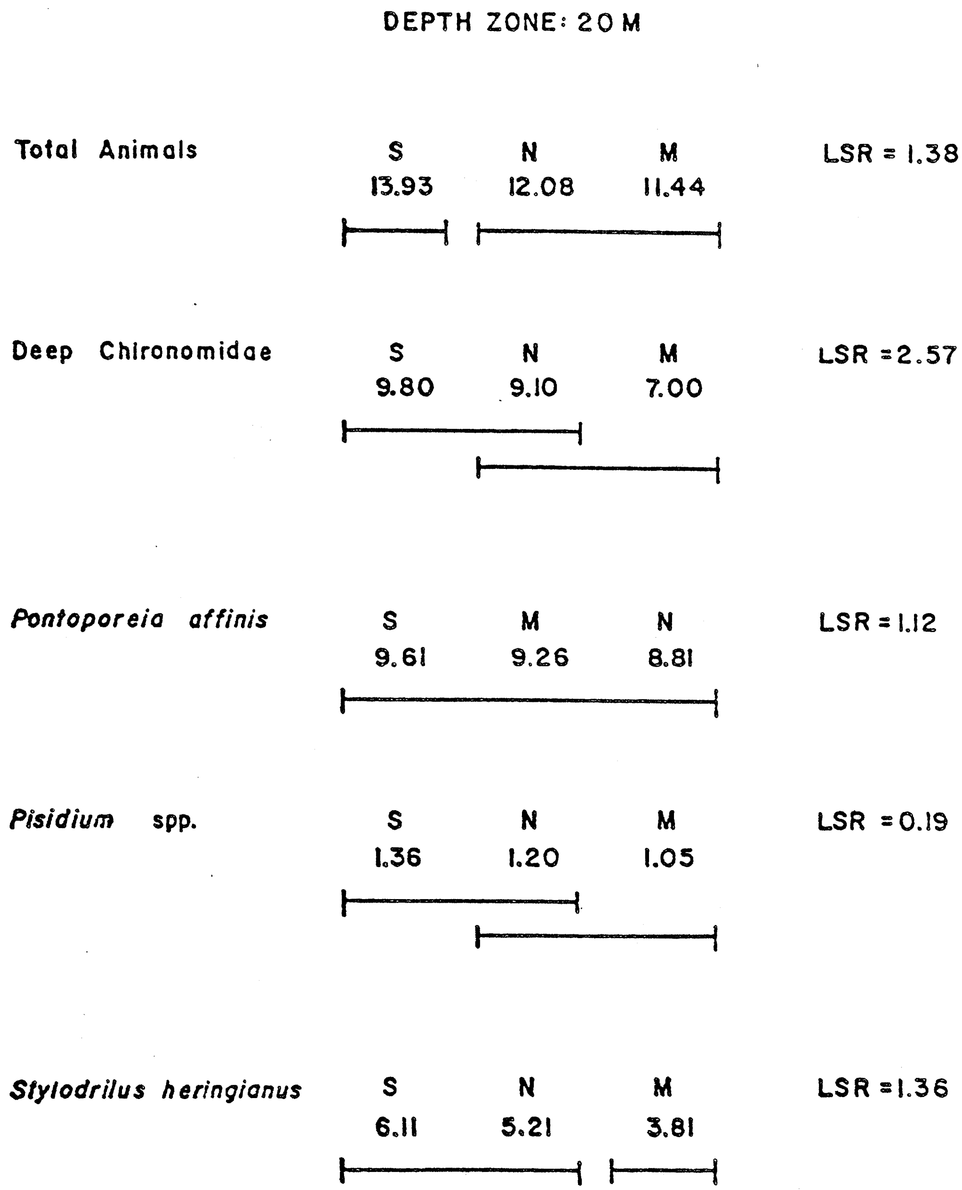


FIG. 165. (continued).

DEPTH ZONE: 25 M

Total Animals	S	N	M	LSR = 1.38
	14.62	14.49	11.61	
Deep Chironomidae	N	S	M	LSR = 2.57
	11.40	11.00	6.90	
Pontoporeia affinis	N	S	M	LSR = 1.12
	10.08	9.89	7.85	
Pisidium spp.	N	S	M	LSR = 0.19
	1.60	1.58	1.25	
Stylodrilus heringianus	S	N	M	LSR = 1.36
	7.07	6.78	6.54	

FIG. 165. (continued).

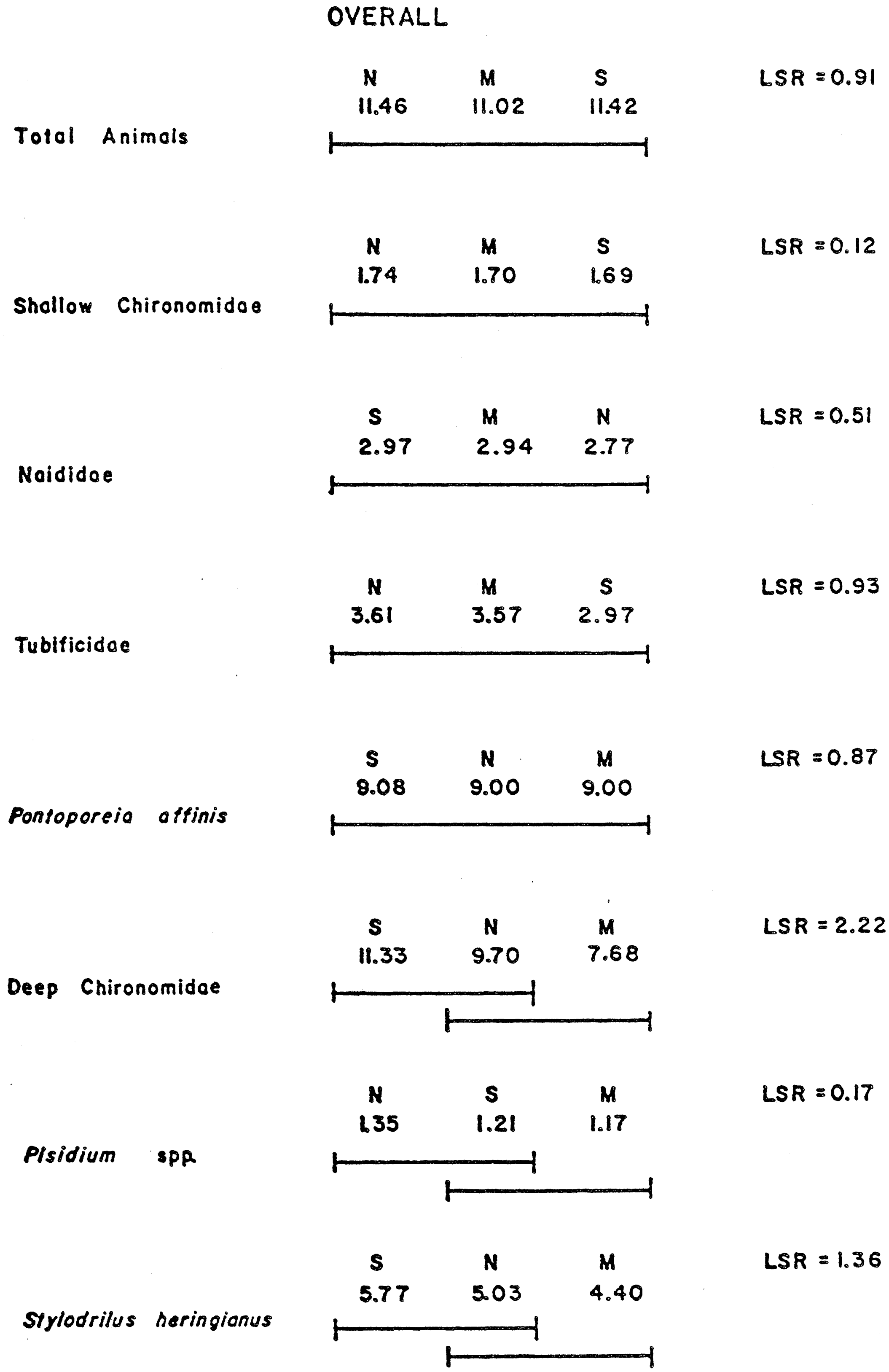


FIG. 165. (continued).

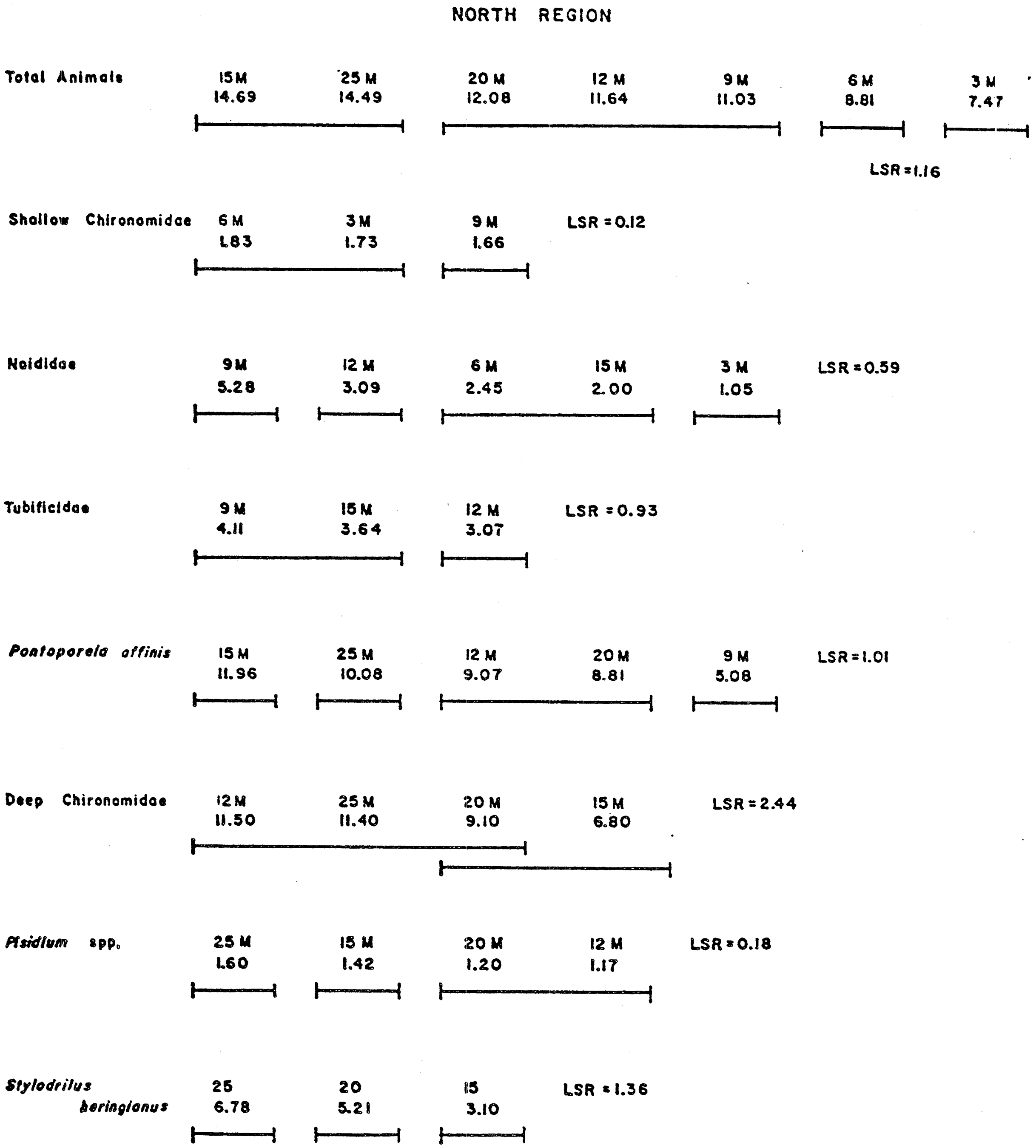


FIG. 166. - Results of multiple comparisons of specific regions across depths (3-25 m) using the Student-Neuman-Keuls technique for the most abundant major taxonomic groups near the J. H. Campbell Power Plant in June 1977. LSR = least significant range at $\alpha = 0.05$.

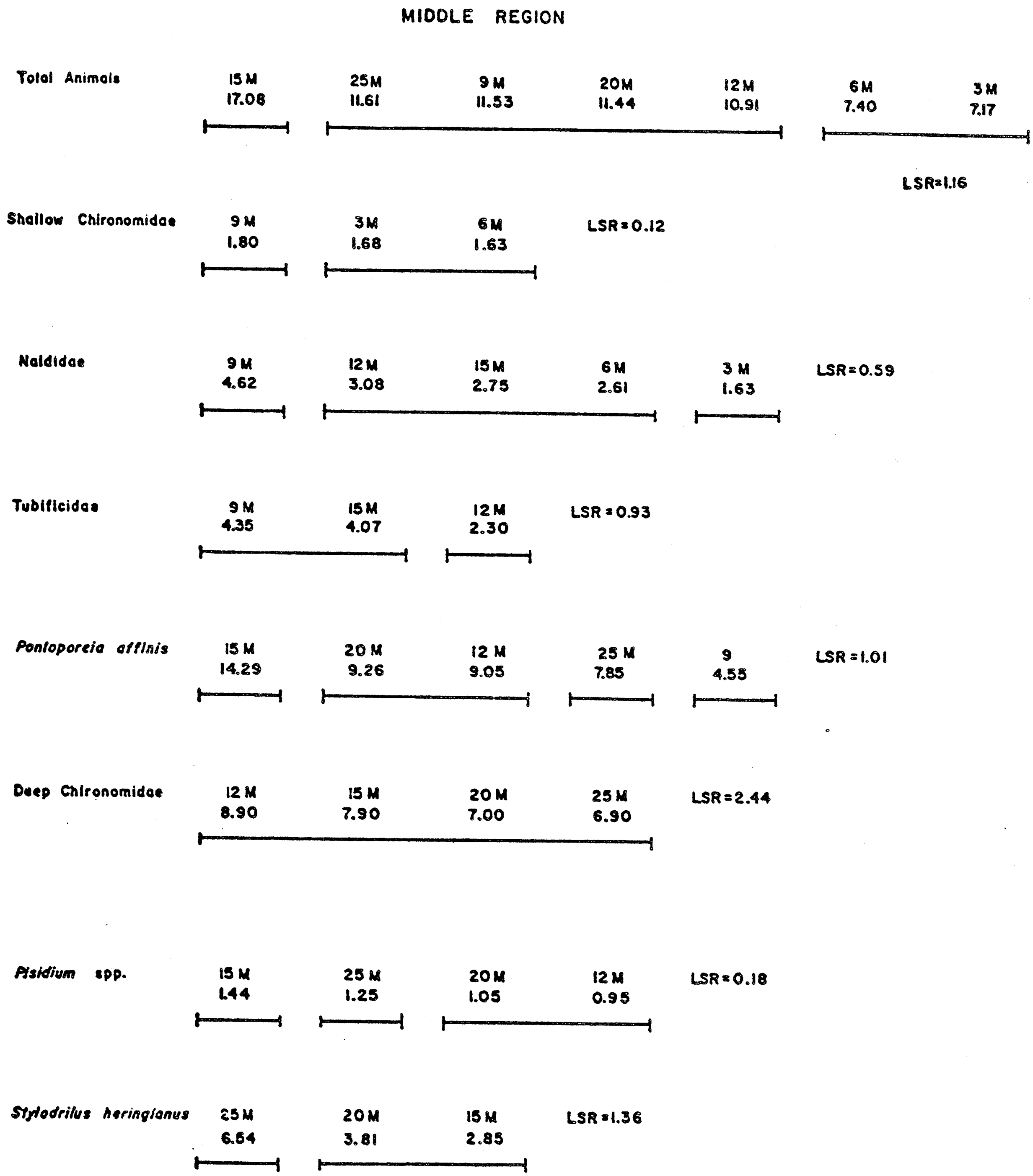


FIG. 166. (continued).

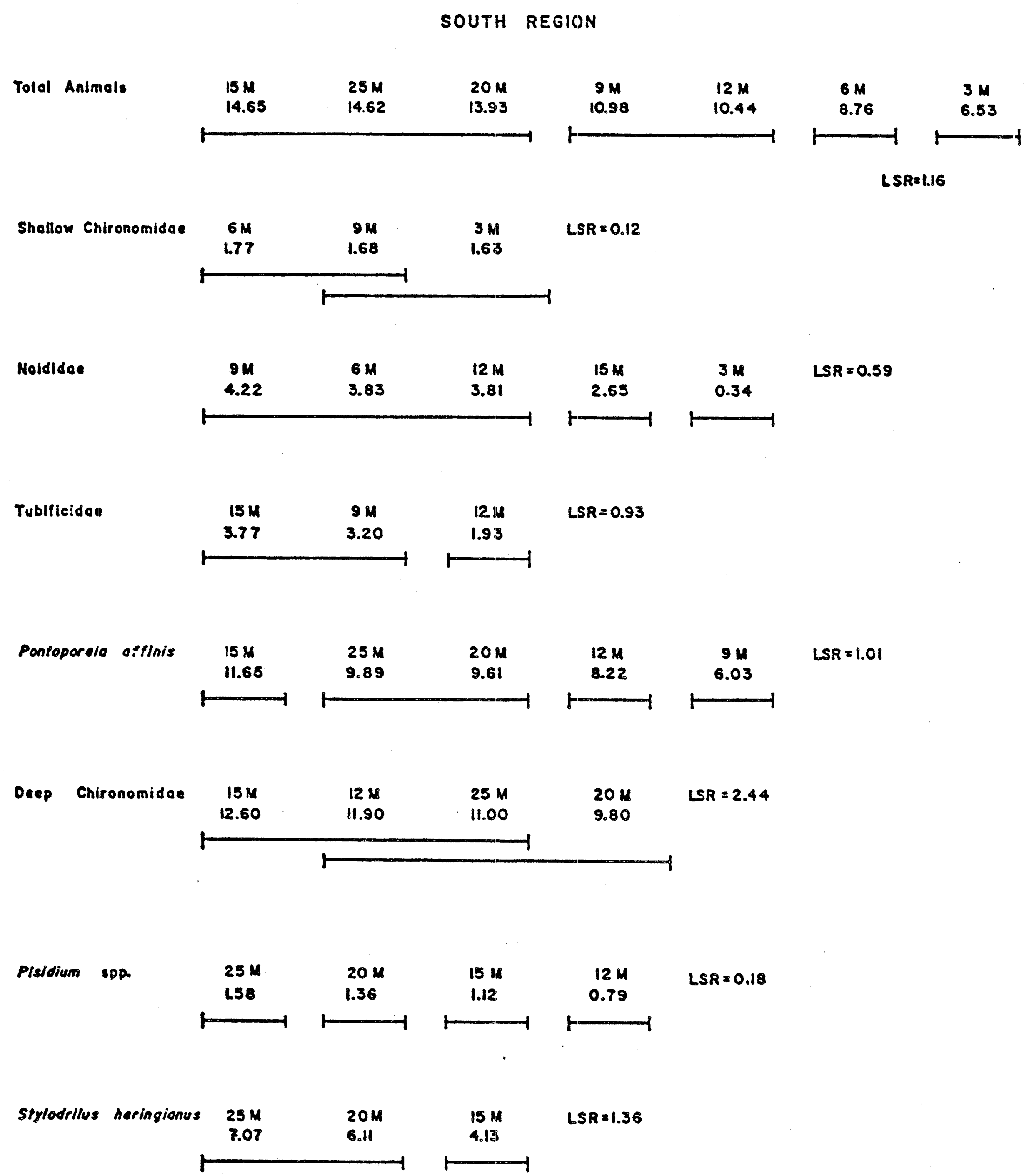


FIG. 166. (continued).

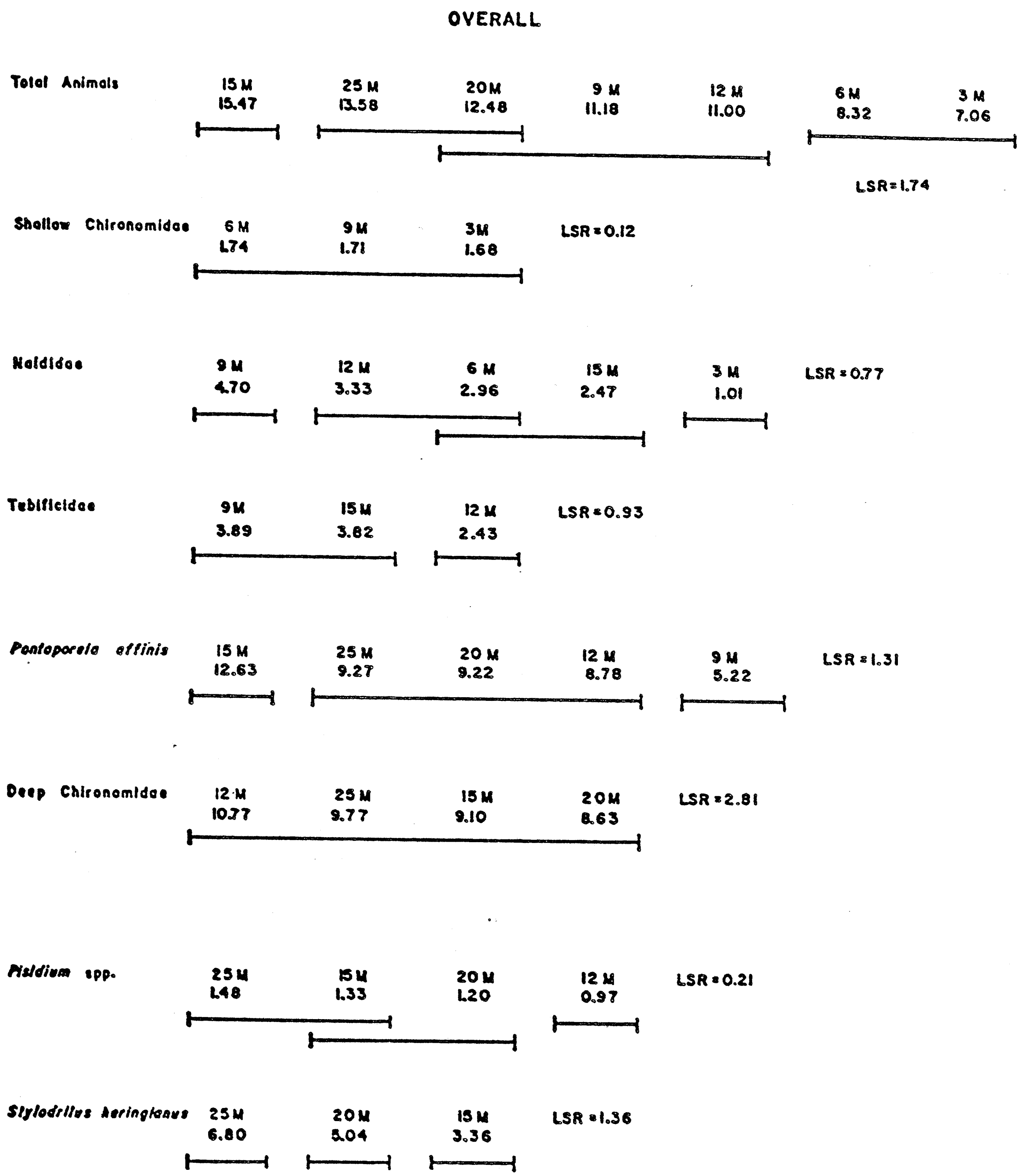


FIG. 166. (continued).

middle region. However, S. cfr. tylus was ~150/m^2 to ~500/m^2 more abundant in the middle than in the north and south regions, respectively.

Naidids at 6 m were significantly more abundant in the south (1085/m^2) than in the middle (570/m^2) or north (455/m^2). Although comprising approximately the same proportion of the population, C. diaphanus, P. michiganensis and U. uncinata were, respectively, 130-360/m^2, 100-150/m^2 and 90-160/m^2 more abundant in the south region than in the middle or north regions.

The 9 m depth zone -- At 9 m there were no significant differences in the density of total animals over regions (Tables 64-70, Fig. 165). However, there were four dominant taxonomic forms present and within these there were differences found. The shallow-zone chironomids were significantly more abundant in the middle (4109/m^2) than in the south (3260/m^2) or north (2982/m^2). The three species contributing the most to the increased abundance in the middle region were Cladotanytarsus sp. (~700/m^2), P. cfr. scalaenum (~250/m^2) and S. cfr. tylus (~200/m^2).

Naidids were significantly more abundant in the north (1739/m^2) than either the middle (1364/m^2) or south (1127/m^2) regions. As in the south region at 6 m, C. diaphanus, P. michiganensis and U. uncinata were species contributing most to the differences noted.

Tubificids at 9 m were significantly more abundant in the middle (1260/m^2) than in the south (806/m^2). Denstiy of tubificids in the north region (1103/m^2) was not significantly different from either region. There were no obvious species abundance differences, but species present in each region were always more abundant in the middle than the south. L. profundicola was found only in the middle and north (48/m^2 and 85/m^2, respectively).

P. affinis was significantly more abundant in the south (2273/m^2) than the middle (1315/m^2) region. The north 9 m region amphipod abundance (1612/m^2) was similar to both the middle and south regions.

The 12 m depth zone -- At the 12 m depth zone there were no significant overall regional differences for total animal abundance (Tables 64-70, Fig. 165). Dominant taxonomic groups present were tubificids, naidids, deep-zone chironomids, P. affinis and Pisidium spp. While tubificids in the middle region (391/m^2) were not significantly more numerous than those caught in the north and south regions, numbers observed in the north (721/m^2) were significantly more abundant than in the south(285/m^2). This was due largely to abundant im w/o hc, P. vejdovskyi and P. freyi occurring only in the north region. L. profundicola occurred in the north (36/m^2) and middle (20/m^2) regions, but not in the south.

Naidids were significantly more abundant in the south ($903/m^2$) than in the north ($618/m^2$) and middle ($619/m^2$) regions. The most abundant naidid in the north and middle regions was P. michiganensis (~$280/m^2$); whereas in the south the most abundant naidid was C. diaphanus ($291/m^2$).

Deep-zone chironomids were significantly less abundant in the middle ($539/m^2$) than they were in the south ($721/m^2$) and north ($697/m^2$) regions. The chironomid taxa which dominated in each region varied. In the south Cladotanytarsus sp. was the most abundant form, more abundant than in the north and middle regions. In the north P. cfr. scalaenum and M. cfr. tuberculata were most abundant, more abundant than in the south and middle regions. In the middle P. cfr. undine was the most abundant species but was only slightly more abundant than those occurring in the other regions.

There were no significant differences in the occurrences of P. affinis across the three regions at 12 m. The density in the north, middle and south was $5123/m^2$, $5111/m^2$ and $4230/m^2$, respectively.

Pisidium spp. were significantly more abundant at 12 m in the north ($964/m^2$) than in the middle ($505/m^2$) and south ($364/m^2$) regions. P. fallax and P. casertanum comprised ~60% of the pisidia in the north region and were two to three times more abundant than those in the middle and south regions.

The 15 m depth zone -- While total animals observed in the north ($13247/m^2$) and south ($13732/m^2$) regions were not different from each other at 15 m, the middle region ($17865/m^2$) was significantly different from the other two regions (Tables 64-70, Fig. 165). Major taxonomic groups dominating in this depth zone were naidids, tubificids, chironomids, P. affinis, Pisidium spp. and S. heringianus. The significant difference noted in the regional distribution of total animal abundance was largely a function of the abundance of P. affinis. P. affinis was significantly more abundant in the middle ($12593/m^2$) than in the north ($8775/m^2$) and south ($8702/m^2$) regions.

Naidids in the south ($491/m^2$) were not significantly different from those in the middle ($509/m^2$) and north ($297/m^2$) regions. However, the number of naidids in the middle was significantly higher than those occurring in the north region. P. michiganensis was more abundant in the middle than either the north or south. P. simplex was very abundant in the south when compared to the other two regions. There were no significant differences in abundance for tubificids and S. heringianus among regions at 15 m.

Chironomids in the south ($764/m^2$) were significantly more abundant than those in the middle ($479/m^2$) and north ($412/m^2$) regions. The primary difference among regions was a preponderance of P. fallax-gr.

(~300/m^2 more) in the south.

Numbers of Pisidium spp. in the middle (1963/m^2) and north (1733/m^2) regions were significantly more abundant than those occurring in the south (1285/m^2). P. casertanum and P. nitidum were the most numerous pisidia in all regions but were 1.4 to 2.4 times more abundant in the north and middle regions when compared to the south region.

The 20 m depth zone -- At 20 m total animal density in the south (12768/m^2) was significantly greater than that found in the north (9278/m^2) and middle (8120/m^2) regions (Tables 64-70, Fig. 165). The dominant taxonomic forms at 20 m were chironomids, P. affinis Pisidium spp. and S. heringianus. The chironomids in the south (594/m^2) were significantly more abundant than those occurring in the middle (424/m^2). The north had an abundance similar to both regions (551/m^2). There were no obvious species abundances that set the south apart from the other two regions. Generally, benthic species found in the south region tended to be slightly more abundant than those in the middle region at 20 m. There were no significant differences in the distribution of P. affinis across regions (5054-5963/m^2) at the 20 m depth contour.

Pisidium spp. were significantly more abundant in the south (2066/m^2) than the middle (854/m^2) region. Number of Pisidium spp. found in the north region at 20 m (1206/m^2) was not different from either region. The south region had twice as many P. nitidum and five times as many P. conventus as there were in the north or middle regions. The north region had two to five times as many P. casertanum as did the middle or south regions.

S. heringianus was significantly more abundant in the south (2909/m^2) when compared to the north (2060/m^2)and middle (1182/m^2) regions.

The 25 m depth zone -- At 25 m abundance of total animals was significantly greater in the south (13399/m^2) and north (13126/m^2) than in the middle region (8375/m^2) (Tables 64-70, Fig. 165). The major taxonomic groups dominating the 25 m depth zone were chironomids, P. affinis. Pisidium spp. and S. heringianus. Chironomids in the north (691/m^2) and south (667/m^2) regions had significantly more animals than the middle region (418/m^2). The middle region at 25 m tended to have slightly lower abundances of the same numerically important major taxonomic groups.

P. affinis was significantly more abundant in the north (6360/m^2) and south (6193/m^2) regions than in the middle region (3818/m^2). Age composition of the population was similar in all three regions.

Pisidium spp. were significantly more abundant in the north ($2588/m^2$) and south ($2685/m^2$) regions than in the middle region ($1133/m^2$). *P casertanum* and *P. nitidum* were two to three times more abundant in the north and south regions than those in the middle region. In the south region *P. conventus* was two to three times more abundant than those occurring in the other regions.

There were no significant differences across the regions at 25 m for *S. heringianus* ($2748-3206/m^2$).

Multiple comparisions within regions across depth zones

The north region -- The general pattern of abundance of animals in the north was that the average number of total animals at the 15 and 25 m depth zones were significantly higher than at the 9, 12 and 20 m depths. Total animal abundance at the 3 and 6 m depths were significantly different from each other and significantly lower than densities observed at all other depths (Tables 64-70, Fig. 166).

Abundance of shallow-zone chironomids was not significantly different between 3 and 6 m. Chironomids at 3 and 6 m were significantly more abundant than those at 9 m. All depths were significantly different from each other when considering naidids, except for the 6 and 15 m depths zones, which were similar. Tubificids were significantly more abundant at 9 and 15 m than they were at 12 m. Average numbers of *P. affinis* found at all depths were significantly different from each other, except at 12 and 20 m, where densities were similar. Abundances of deep-zone chironomids were significantly higher at 12 and 25 m than at 15 m. Deep-zone chironomid abundance at 20 m was similar to abundances observed at the 12, 15 and 25 m depths. Average numbers of *Pisidium* spp. at all depths were significantly different from each other, except at 12 and 20 m, where densities were similar . Average numbers of *S heringanus* from all depth zones were significantly different from each other.

The middle region -- The general trend of benthic abundance in the middle region showed that the 15 m depth contour contained significantly higher numbers of total animals than any other depth zone. Abundance of total animals at the 9, 12, 20 and 25 m depths was similar. The 3 and 6 m depths were similar in numbers of animals observed and contained the lowest abundance of animals found at any depth zone in the middle region (Tables 64-70, Fig. 166).

Abundance of shallow-zone chironomids was significantly higher at 9 m than at 3 and 6 m which had similar numbers of chironomids. Number of naidids found at 9 m in the middle region was significantly higher than those found in the 6, 12 and 15 m depth zones, which contained similar numbers of animals. Tubificids were significantly more abundant

at 9 and 15 m than they were at 12 m. P. affinis and Pisidium spp. had similar patterns in that average densities across depths in the middle region were significantly different except at 12 and 20 m. Deep-zone chironomids had no significant differences in abundance across observed depth zones. Abundance of S. heringianus at 25 m was significantly higher than numbers observed at 15 and 20 m, where densities were similar.

The south region -- The general pattern of benthic abundance in the south region indicated that the 15, 20 and 25 m depth contours contained similar abundances of total animals and a significantly greater number of benthic macroinvertebrates than the remaining depth zones. Of the remaining depth zones the 9 and 12 m depths had similar abundances of total animals. Total animal abundances at the 3 and 6 m depths were significantly different from each other and significantly lower than densities at other depths (Tables 64-70, Fig. 166).

Shallow-zone chironomids were significantly more abundant at 6 m when compared to those at 3 m. Shallow-zone chironomid abundance at 9 m was similar to abundances observed at 3 and 6 m. The density of naidids at the 6, 9 and 12 m depths were similar but significantly higher than numbers found at the 3 and 15 m depths. Numbers of naiads at 3 and 15 m depths were significantly different from each other. Tubificids were significantly more abundant at 9 and 15 m than they were at 12 m. Average abundances of P. affinis at all depths were significantly different from each other except at 20 and 25 m which had similar numbers of P. affinis. The deep-zone chironomids had wide overlapping abundances among depth zones in the south region with only those at 15 m and 20 m having densities significantly different from each other. Densities of Pisidium spp. at all depth zones were significantly different from each other. Numbers of S. heringianus found at 20 and 25 m were similar, but significantly more abundant than densities observed at 15 m.

Lake Michigan - Discussion

Community Structure with Respect to Depth --

Distribution of benthos over depth in the vicinity of the Campbell Plant was similar to general patterns noted for other Lake Michigan studies. The basic structural zonation of the near-shore benthos has been defined by Mozley and Garcia (1972), Mozley (1974) and Mozley and Winnell (1975). These studies have shown that the 0-8 m depth zone in the lake is comprised mainly of chironomids and naidids capable of living in a harsh, physical environment characterized by severe wave interaction with the sediments. Animals in this zone evidently are able to utilize the spaces between sand grains and due to wave action are able to relocate often without much effect on reproductive success and

exploitation of a food source.

The 3-6 m depths were considered a wave-controlled environment. These depths were dominated by three chironomids, *R.* cfr. *demeijerei*, *S.* cfr. *tylus* and *Chironomus* sp., that burrow between the loosely packed and larger grains of sand. While these chironomids were present at greater depths, their abundances were greatly reduced and replaced by other forms more adapted to deeper water.

At 9-12 m the effect of waves apparently was less intense than at 3-6 m, since the tube builder, *Cladotanytarsus* sp., became very abundant. Presence of a tube builder and several other forms characteristic of a more silted-sand environment (e.g., tubificids, *P. affinis* and pelecypods) suggests an increasingly stable environment and a more diverse community when compared with shallower habitats. The effect of increased alongshore currents and larger waves do not allow silt deposits to build up at these depths, except in localized pockets. Sediments continue to be carried offshore and subsequently deposited in deeper water. Therefore, the above in combination with other physical factors (e.g., light attenuation and temperature), causes the maximum abundance of tubificids to be in the deeper part of the lake.

Peak abundances of animals in Lake Michigan occurred from 25-35 m in Robertson and Alley's study (1966). In a lake-wide survey Alley and Mozley (1975) showed that *P. affinis* peaked in maximum abundance at 25 m ($8900/m^2$), oligochaetes at 35 m ($4000/m^2$) and sphaeriids at 35 m ($4400/m^2$). Mozley and Alley (1973) indicated that amphipods and oligochaetes peaked from 20 to 60 m. Since oligochaetes in Mozley and Alley's (1973) study were a mixture of tubificids and *S. heringianus*, significance of the worms reaching maximum abundance near 35 m is likely a reflection of the number of *S. heringianus* present.

Mozley and Garcia (1972) pointed out that sediments near the D.C. Cook Plant from 15-35 m often included fractions of clay and were layered. In the present study, sediments were described as slightly silty, fine sand at 15 m, medium to coarse silty-sand at 20 m and fine to coarse silty-sand (possibly some clay) with some pebbles at 25 m suggesting an exposed layer of moraine protruding into the lake. Thus, benthic distributions were affected since sediment patterns were not similar and even. While numbers of animals may increase more evenly in other study areas at these depths, a general decrease was noted near the Campbell Plant.

The outcropping of moraine (based on visual sediment descriptions) appeared more developed in the north and middle regions than in the south region. Due to the varying degrees of exposure of moraine, major taxonomic groups expected to be numerous near the 20 m depth zone, i.e. tubificids, *P. affinis*, pelecypods, decreased relatively more in

abundance in the north and middle regions than in the south region. The only exception to this pattern was S. heringianus which did not appear to be affected by the layer of moraine to the extent other groups were affected.

Based on abundances of animals observed, it appeared the middle region may have been the most severely affected region with respect to the moraine layer. In all cases tested, except P. affinis, densities of animals in the middle region were consistently less abundant at the depth of greatest morainal exposure (20 m). In all cases tested at 25 m, except S. heringianus, animals in the middle region were the least abundant when compared to their corresponding densities in other regions. Thus the effect of the moraine may have been more severe in the middle region when compared to other regions at 25 m.

Presence of a wave-controlled, nearshore area (3-6 m) and an offshore outcropping of moraine (20-25 m) greatly affected the distributional patterns of benthic macroinvertebrates observed. The 9-15 m depth zones appeared to be an area of intermittently stable environment that supported the greatest diversity and density of organisms, in particular P. affinis at 15 m. The distributional patterns noted at 3-6 m corresponded to results from other surveys in Lake Michigan (Truchan 1970). The 9-15 m depth zones were similar in some respects and dissimilar in others when compared with the literature. While chironomid distribution was similar to published results (Mozley 1975), tubificid abundance usually does not reach maximum abundance at 9-15 m as was found at Campbell. Data from the Cook Plant indicate tubificids in this area of Lake Michigan peak from 15-25 m. In addition P. affinis does not usually peak at 15 m as was observed at Campbell but occurs somewhat deeper (25-40 m) (Mozley and Winnell 1975). While under more usual conditions abundance of many of the major taxonomic groups would be expected to increase with increasing depth from 15-35 m, this was not the case in the more limited depth range (15-25 m) sampled at the Campbell Plant. In conclusion it would appear that presence of the morainal layer at 20 m altered the distribution of benthic macroinvertebrates from the more usual pattern recorded in the literature.

Community Structure with Respect to Region --

The 3-6 m depth zone in the middle region was the area around the plant that would be expected to be most seriously affected by the existing thermal discharge. Truchan (1970) surveying this area found significant differences in the number of species present near the outfall of the plant when compared with areas more distant. Although abundances of organisms were elevated in the outfall area there were no statistical differences observed when compared to areas more distant. These data were based on two replicates per station. The dominant

organisms at the (1.5-7.5 m) stations were chironomids. Complete comparisons of species lists are not possible due to advances in taxonomic studies. However, it does appear that R. cfr. demeijerei, Cryptochironomus sp. 1, Chironomus sp. and Cladopelma sp. were species found in both studies. Mozley (1974) indicated that Parachironomus cfr. abortivus was also found by Truchan. In addition to P. cfr. abortivus the present study also found Nanocladius sp., Paratendipes sp. and an Orthocladiini sp. 2 only in the outfall area. Nanocladius sp. and Paratendipes sp. were found in Pigeon Lake and may inhabit the discharge canal as well.

Aside from the presence/absence of particular chironomid species noted in the middle region as opposed to the south and north regions, the most obvious difference was in the abundance of P. affinis across regions at 15 m. A large number of P. affinis were located in the middle region, for which there are a large number of possible causes. Vascotto (1976) studying P. affinis in Canadian lakes found that young P. affinis occurred just off the bottom and not in the sediments. A result of this activity by the amphipod could be increased numbers in pockets or at given depths due to a swirling, eddying current action. A second possibility to explain the increased numbers observed at 15 m in the middle region is that upwelling brought young P. affinis inshore from deeper water. A third possibility to consider is that there may have been a differential factor, such as food, being concentrated in a specific area by wave and current action. Increased food resources may come either from input from the discharge canal or from winnowing activities on the exposed moraine or both simultaneously. A fourth cause may be a seasonal factor acting in combination with one or more of the above.

Regardless of which hypothesis is true, it is important to note that although the number of P. affinis were most abundant in the middle region at 15 m, P. affinis peaked at 15 m in all regions. At present the scope of the data is not large enough to differentiate among proposed hypotheses.

Lake Michigan - Summary

A triplex Ponar grab was used to sample the benthic macroinvertebrates at 3,6,9,12,15,20 and 25 m in Lake Michigan near the J.H. Campbell Plant in June 1977. The area near the plant was partitioned into three regions (north, middle and south - see METHODS - BENTHOS). With respect to depth there were three major divisions in the distribution of animals. The first division (3-6 m depth zone) was characterized as a nearshore, wave-controlled area and was dominated by the presence of chironomids and naidids. The chironomids; R. cfr. demeijerei, Chironomus sp. and S cfr. tylus, and the naidids; C. diaphanus, P. michiganensis, U. uncinata, N. variabilis and N. elinguis

were the most abundant genera present at 3-6 m.

The second division (9-15 m depth zone) was characterized as an intermittently stable and diverse habitat. Although this area contained the greatest diversity of the three divisions noted, the 9-15 m depth zone was dominated by *P. affinis* which comprised up to 67% of the animals present. Tubificids and gastropods attained their maximum densities in the 9-15 m depth zone.

The third division (20-25 m) was characterized by the presence of an offshore layer of exposed moraine. While *Pisidium* spp., *S. heringianus* and *P. affinis* were the most abundant animals at 20-25 m, their respective densities were variously affected by the moraine. Of the three taxa above, *S. heringianus* appeared to be the least affected. The most notable difference among regions was the high density of *P. affinis* in the middle region at 15 m when compared to any depth in any region. While differences among regions for other taxa occurred, none were as notable as *P. affinis*. Differences among regions for many taxa appeared to have been correlated with the presence of the morainal layer.

Sample replicability could be limited to six replicates per sample site if a least detectable true difference of 143 animals between sample sites is acceptable (α=0.05, p=0.95). Although the determined sample replicability (six) included depth and regional variations, it did not include any seasonal variation.

Pigeon Lake - General

Pigeon Lake is a small eutrophic estuarine lake near Port Sheldon, Michigan on the central-eastern coast of Lake Michigan. Lake Shore Avenue separates Pigeon Lake into an eastern and western basin. The eastern basin and the eastern end of the western basin are primarily littoral. The central portion and western end of the western basin are deep (7 m) with slopes leading to a narrow littoral zone near the edge of the lake. Pigeon Lake receives water from Pigeon River and from Lake Michigan (due to intake pumps at the Campbell Plant).

Previous sampling in Pigeon Lake is limited to Tack et al. (1973) who indicated tubificids were most abundant in the western end of the western basin, amphipods were most abundant in the eastern end of the western basin and that chironomids were the most abundant insect. These results were supported by the present study. However, the major difference between studies was a more exacting quantification of animals with oligochaetes and chironomids treated in greater taxonomic detail. In addition, samples were taken in the eastern basin where benthic macroinvertebrate samples had not been taken in previous studies.

It was the purpose of this study to determine the quantities of

animals present in Pigeon Lake in various habitat types. Taxonomic determinations were carried as far as possible to aid in associating groups of animals with differing habitat types and to determine how many different forms of macroinvertebrates inhabited Pigeon Lake.

Pigeon Lake - Western Basin

Transect 1 - Station PL11 --

The first transect in the western basin of Pigeon Lake was PL11 which had only one station (PL11). Station PL11 was 7 m deep and was sampled as representative of the benthic community inhabiting the maximum depth found in Pigeon Lake. Sediments were composed entirely of silt and detritus.

Station PL11 had more animals/m^2 than any other station sampled in Pigeon Lake (Table 82). Mean abundance of total animals was 130168/m^2. The most numerous forms, tubificids and chironomids, comprised 97% and < 3% of the total animals present, respectively (Table 83).

When compared to other stations in Pigeon Lake, the second lowest number of taxa (19) occurred at PL11 (Tables 82 and 84), and the largest number of tubificids were found at PL11; most were immature forms of tubificids. However, it is believed that these immatures were _L. hoffmeisteri_, _L. cervix_ and _Tubifex tubifex_, which were present in low abundance in the samples. Thus in 2-6 wks these three forms would the dominants. The most abundant identifiable tubificid was _A. pluriseta_. The greatest number of _A. pluriseta_, _Peloscolex multisetosus multisetosus_ and _P. multisetosus longidentis_ occurred at PL11. _Chironomus_ spp. was the most numerous chironomid at PL11.

Transect 2 - Station PL24 --

The deepest station along the second transect (PL2) was PL24 (5 m). Station PL24 was sampled as representative of the habitat at intermediate depths in Pigeon Lake. The environment sampled consisted of two sediment types. The first type (from replicates A and B) consisted of silty sand with considerable detritus. Sediments of replicate C were silt with some sand. Like PL11, this station did not have any aquatic macrophytes present.

Station PL24 samples contained 44 taxa (Tables 82 and 84). Chironomids were the most species-rich group with 15. When compared to other stations,the greatest number of tubificid (11) and second greatest number of naidid taxa (10) occurred at PL24.

Station PL24 located in the western end of the western basin had the third greatest number of total animals (67776/m^2) and along with

TABLE 82. Abundance ($\#/m^2$) of the most numerous benthic taxa collected from Pigeon Lake in the vicinity of the J.H. Campbell Plant, June 1977. ($\bar{X}$ = mean, S.E. = standard error).

	Station											
	PL11		PL24		PL25		PL31		PL32		PL41	
Taxa	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.
Chironomidae	3296.73	744.45	2957.77	772.67	11658.25	1052.13	19893.48	11937.61	4160.80	3673.59	7504.10	3659.20
Chironomus spp.	2339.63	1314.22	1488.85	1173.43	1389.15	285.34	923.89	265.87	3197.05	2874.32	166.17	166.17
Procladius sp. 1	638.08	638.08	132.93	70.34	13.29	6.65	19.94	11.51	850.77	850.77	159.52	
Psectrocladius sp. 1	106.35	106.35	638.08	92.10	2778.31	392.32	405.45	239.93			332.33	86.41
Cricotopus spp.	106.35	106.35	53.17	53.17	3549.32	1327.47	8049.11	5362.94	6.65	6.65	1721.49	1402.45
Polypedilum cfr. scalaenum			265.87	140.68								
Paratendipes sp.			26.59	26.59								
Robackia cfr. demeijeri			26.59	26.59								
Dicrotendipes sp.			26.59	26.59	66.47	56.79	2758.37	1732.58	106.35	106.35	1827.83	802.93
Tanytarsus sp.			26.59	26.59			352.27	352.27			79.76	79.76
Endochironomus sp.					13.29	6.65	3143.87	2187.12			857.42	697.90
Cladotanytarsus sp.					1229.63	308.12	2060.47	1256.40			1269.53	587.29
Psectrocladius sp. 2					6.65	6.65	664.67	385.68			26.59	26.59
Parachironomus cfr. abortivus					132.93	112.99	525.09	271.54			272.51	23.96
Nanocladius sp.					1203.05	479.16	119.64	99.70			106.35	53.17
Pseudosmittia spp.												
Polypedilum cfr. halterale					59.82	50.18	239.28	111.02			119.64	60.92
Ceratopagonidae					6.65	6.65	119.64	109.82			26.59	26.59
Lepidoptera					13.29	13.29	564.97	284.41			66.47	56.79
Tubificidae	126127.17	19104.56	61674.44	46053.14	49185.33	15158.79	790.95	196.84	5849.07	5371.30	1229.64	711.55
im w/o hc	39029.23	11073.85	17294.63	10176.05	41508.43	12757.62	664.67	166.96	2339.63	2020.59	837.48	479.11
im w/hc	76569.60	13480.46	33047.23	30703.71	2685.25	1240.69			3190.40	3190.40	212.60	212.60
Aulodrilus pluriseta	3828.48	974.68	2924.53	1035.17	1256.22	776.47			319.04	184.20		
Limnodrilus hoffmeisteri	1701.55	927.11	2499.15	2264.09	2219.99	559.07	112.99	112.99			119.64	60.92
Limnodrilus cervix	850.77	562.73	1488.85	1488.85	478.56	340.73						
Peloscolex multisetosus multisetosus	1276.16	638.08			73.11	73.11						
Peloscolex multisetosus longidentis	1595.20	319.04	425.39	425.39	106.35	106.35						
Tubifex tubifex	425.39	425.39	425.39	425.39								
Potamothrix bedoti			1063.47	1063.47								
Potamothrix vejdovskyi			1887.65	977.22								

TABLE 82. (continued).

	Station											
	PL11		PL24		PL25		PL31		PL32		PL41	
Taxa	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.
Naididae	638.10		1728.13	509.33	2313.05	1655.07	578.25	313.38	425.40	425.40	86.41	86.41
Nais variabilis	212.69	212.69	531.72	372.22	451.97	284.18	225.99	113.58				
Nais simplex	106.35	106.35	132.93	70.34	584.91	348.68	119.64	119.64	212.69	212.69		
Vejdovskyella intermedia			53.17	53.17					212.69	212.69		
Stylaria lacustris					126.29	126.29	225.99	112.99			86.41	86.41
Hirudinea					1488.86	1270.82	1741.43	764.20	212.69	212.69	239.27	46.06
Helobdella stagnalis					146.23	108.81	1415.74	943.52			159.52	79.76
Amphipoda			265.86	191.72	8248.51	1962.81	7856.36	4084.65	212.69	212.69	6619.67	927.38
Gammarus sp.			265.86	191.72	5516.73	1340.65	1043.53	342.35			4572.91	472.05
Hyalella azteca					2485.85	423.98	6812.83	3742.30	212.69	212.69	1641.73	142.09
Isopoda			79.76	79.76	8308.34	1948.89	2472.56	477.94	638.03	638.08	2166.82	83.03
Asellus sp.			79.76	79.76	7803.19	1698.16	2246.57	261.85	638.08	638.08	1462.27	46.53
Lirceus sp.					505.15	250.73	225.99	216.09			704.55	326.50
Gastropoda			159.53	159.53	5636.37	2423.34	890.65	541.73	106.35	106.35	611.51	217.62
Amnicola sp.			132.93	132.93	4380.15	1961.17	232.63	213.00			159.52	92.10
Sphaeriidae			319.03	243.67			112.99	112.99				
Pisidium spp.			319.03	243.67			112.99	112.99				
Hydracarina	106.35	106.35	292.45	174.34	119.64	99.70	225.99	216.09			239.28	138.15
Turbellaria			245.93	198.18	957.12	957.12	112.99	112.99	212.69	212.69		
Total Animals	130168.35	18393.98	67776.03	47170.27	88686.50	19209.48	35739.13	17124.09	11817.79	10685.08	19162.37	4131.82

TABLE 82. (continued).

Taxa	PLA2 $\overline{X}$	PLA2 S.E.	PLX1 $\overline{X}$	PLX1 S.E.	PLX2 $\overline{X}$	PLX2 S.E.	PLX3 $\overline{X}$	PLX3 S.E.	PL51 $\overline{X}$	PL51 S.E.	PL52 $\overline{X}$	PL52 S.E.	PL53 $\overline{X}$	PL53 S.E.
Chironomidae	5084.70	1028.86	7769.97	1700.81	864.08	289.02	9943.41	1895.33	1110.00	148.47	1934.18	99.70	3349.92	926.80
<u>Chironomus</u> spp.	591.56	238.43	106.36	40.44	338.98	129.74	119.64	59.13	139.58	50.18	126.29	17.59	252.58	143.04
<u>Procladius</u> sp. 1	265.87	191.72	558.32	98.36	6.65	6.65	438.68	161.17			252.57	56.79	545.03	209.87
<u>Psectrocladius</u> sp. 1	212.69	106.35	704.55	272.51	19.94	11.51	79.76	41.51			26.59	13.29	53.17	26.59
<u>Cricotopus</u> spp.	1123.29	338.46	3649.02	1029.44	126.29	6.65	4094.35	1094.12	425.39	95.86	471.91	154.60	418.74	143.79
<u>Polypedilum</u> cfr. <u>scalaenum</u>					86.40	17.59								
<u>Paratendipes</u> sp.					6.65	6.65	13.29	6.65					299.10	120.19
<u>Robackia</u> cfr. <u>demeijeri</u>					39.88	39.88								
<u>Dicrotendipes</u> sp.	651.37	483.15	538.38	203.67	39.88	11.51	777.66	102.32	112.99	23.96	259.22	124.53	312.39	87.17
<u>Tanytarsus</u> sp.			26.59	17.59			99.70	50.18			33.23	17.59	252.57	122.02
<u>Endochironomus</u> sp.	538.38	109.82	265.87	76.65	26.59	17.59	2093.70	309.12	272.51	129.40	79.76	30.46	159.52	52.76
<u>Cladotanytarsus</u> sp.	691.25	191.72	179.46	11.51	39.88	39.88	279.16	158.27	26.59	26.59	46.53	23.96	139.59	70.04
<u>Psectrocladius</u> sp. 2	106.35	106.35	73.11	26.59			33.23	23.96			6.65	6.65	19.94	11.51
<u>Parachironomus</u> cfr. <u>abortivus</u>	319.04	184.20	206.05	47.93	6.65	6.65	119.64	60.92	26.59	26.59	19.94	11.51	39.88	11.51
<u>Nanocladius</u> sp.	53.17	53.17	531.73	202.81			372.21	213.00	26.59	26.59	39.88	30.46	139.59	75.50
<u>Pseudosmittia</u> spp.			6.65	6.65	39.88	39.88							6.65	6.65
<u>Polypedilum</u> cfr. <u>halterale</u>	159.52	92.10	26.59	17.59	13.29	6.65	558.32	116.84			245.93	158.83	146.23	26.59
Ceratopogonidae	106.35	106.35	26.59	17.59	46.53	37.01	279.16	69.07	53.17	26.59	33.23	23.96	66.47	64.10
Lepidoptera	106.35	106.35	59.82	19.94			584.91	138.31			26.59	26.59	53.17	17.59
Tubificidae	485.22	152.86	385.50	69.40	146.23	47.93	332.33	166.56	651.35	289.71	159.52	98.36	179.46	86.92
im w/o hc	272.51	46.53	26.59	6.65	99.70	11.51	206.05	142.09	385.51	193.10	86.41	51.91	26.59	13.29
im w/hc			26.59	17.59	13.29	6.65	33.23	33.23	66.47	13.29	59.82	34.54	93.05	74.01
<u>Aulodrilus pluriseta</u>														
<u>Limnodrilus hoffmeisteri</u>	212.69	106.35	6.65	6.65			13.29	13.29	179.46	149.66	6.65	6.65	13.29	6.65
<u>Limnodrilus cervix</u>														
<u>Peloscolex multisetosus multisetosus</u>			292.46	65.46										
<u>Peloscolex multisetosus longidentis</u>														
<u>Tubifex tubifex</u>														
<u>Potamothrix bedoti</u>														
<u>Potamothrix vejdovskyi</u>														

TABLE 82. (continued).

Taxa	Station													
	PL42		PLX1		PLX2		PLX3		PL51		PL52		PL53	
	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.	$\bar{X}$	S.E.
Naididae	1382.51	1226.46	777.65	329.05	491.84	169.71	525.09	485.75	339.01	220.55	232.75	37.05	297.45	46.53
Nais variabilis	372.21	231.78	358.94	182.77	146.23	46.53	146.23	108.81	186.11	106.35	39.88	19.94	73.11	37.01
Nais simplex	372.21	372.21	199.40	71.89	285.81	113.58	112.99	112.99	73.11	40.43	152.87	6.65	79.76	50.18
Vejdovskyella intermedia														
Stylaria lacustris	319.04	319.04	79.76	30.46	13.29	13.29	199.40	199.40	13.29	13.29	6.65	6.65	39.88	30.46
Hirudinea	478.56	243.67	139.59	50.19	53.17	17.58	910.61	216.08	152.87	93.76	697.90	254.04	618.13	270.72
Helobdella stagnalis	53.17	53.17	132.93	47.93	33.23	23.96	844.13	262.61	152.87	93.76	664.67	227.45	584.91	277.33
Amphipoda	1063.47	531.73	3356.57	584.61	119.64	59.82	6088.35	1215.43	1774.66	1170.27	677.96	170.02	2040.52	791.63
Gammarus sp.	903.95	372.21	2100.35	405.61	106.35	46.53	2206.69	589.76	1515.44	1018.89	558.32	132.77	1395.79	551.99
Hyalella azteca	159.52	159.52	1222.99	145.77	13.29	13.29	3795.25	549.02	225.99	118.15	106.35	23.96	545.03	167.75
Isopoda	159.52	92.10	465.27	46.53			2512.44	948.99	232.63	133.43	711.19	236.59	2957.77	1042.88
Asellus sp.	159.52	92.10	465.27	46.53			2479.21	925.03	232.63	133.43	711.19	236.59	2731.78	935.91
Lirceus sp.							33.23	23.96					225.99	106.97
Gastropoda	531.73	281.36	299.10	39.90	26.59	13.29	970.41	242.68	392.15	173.20	219.35	159.94	319.05	83.03
Amnicola sp.			99.70	11.51	26.59	13.29	797.60	252.49	378.86	180.93	199.40	149.66	299.10	71.89
Sphaeriidae	106.35	106.35	6.65	6.65	172.80	118.16	59.82	30.46			6.65	6.65	19.94	11.51
Pisidium spp.	106.35	106.35			159.52	113.38	59.82	30.46			6.65	6.65	19.94	11.51
Hydracarina	212.69	106.35	797.60	249.32	19.94	11.51	664.67	6.65	13.29	13.29	232.63	78.36	106.35	6.65
Turbellaria	53.17	53.17	6.65	6.65							6.65	6.65	13.29	13.29
Total Animals	10249.17	2432.67	4965.06	1947.02	5018.23	1117.73	10501.73	3047.50	14429.93	2068.15	1954.12	581.12	24293.57	2494.54

TABLE 83. Percent composition of major benthos taxonomic groups collected from Pigeon Lake in the vicinity of the J. H. Campbell Plant, June 1977.

Taxa	Station												
	PL11	PL24	PL25	PL31	PL32	PL41	PL42	PLX1	PLX2	PLX3	PL51	PL52	PL53
Malacrustaceans		0.51	18.67	28.90	7.20	45.85	11.93	26.49	6.12	35.40	40.43	27.68	47.59
Gammarus sp.		0.39	6.22	2.92		23.86	8.82	14.56	5.44	9.08	30.52	11.13	13.29
Hyalella azteca			2.80	19.06	1.80	8.57	1.56	8.48	0.68	15.62	4.55	2.12	5.19
Asellus sp.		0.12	8.80	6.29	5.40	7.63	1.56	3.22		10.21	4.69	14.17	26.01
Sphaeriidae		0.47		0.32			1.04	0.05	8.84	0.25		0.13	0.19
Gastropoda		0.24	6.36	2.49	0.90	3.19	5.19	2.07	1.36	3.99	7.90	4.37	3.04
Hirudinea			1.68	4.87	1.80	1.25	4.67	0.97	2.72	3.75	3.08	13.91	5.89
Chironomidae	2.53	4.36	13.15	55.66	35.21	39.16	49.61	53.85	44.22	40.93	22.36	38.54	31.90
Naididae	0.49	2.55	2.61	1.62	3.60	0.45	13.49	5.39	25.17	2.16	6.83	4.64	2.78
Tubificidae	96.90	91.00	55.46	2.21	49.49	6.42	4.73	2.67	7.48	1.37	13.12	3.18	1.71
Others	0.08	0.87	2.08	3.92	1.80	3.54	9.34	8.43	4.08	12.15	6.02	7.55	6.90

TABLE 84. Occurrence of benthos taxa from Pigeon Lake at various stations in the vicinity of the J. H. Campbell Plant, June 1977, presence and absence denoted by an X or blank respectively.

Taxa	Station												
	PL11	PL24	PL25	PL31	PL32	PL41	PL42	PLX1	PLX2	PLX3	PL51	PL52	PL53
Annelida													
Oligochaeta													
Tubificidae													
i m w/o hc	X	X	X	X	X	X	X	X	X	X	X	X	X
i m w/hc	X	X	X		X	X		X	X	X	X	X	X
Aulodrilus pluriseta	X	X	X		X								
Aulodrilus pigueti	X	X	X					X		X	X	X	X
Aulodrilus limnobius	X	X	X	X						X			
Limnodrilus hoffmeisteri	X	X	X	X		X	X	X		X	X	X	X
Limnodrilus cervix	X	X	X										
Limnodrilus claparedianus			X										
Limnodrilus profundicola			X										
Limnodrilus udekemianus				X		X							
Peloscolex freyi			X			X			X				
Peloscolex multisetosus multisetosus	X		X					X					
Peloscolex multisetosus longidentis	X	X	X										
Tubifex tubifex	X	X											
Ilyodrilus templetoni	X	X	X							X	X		X
Potamothrix vejdovskyi		X											
Potamothrix moldaviensis		X											
Potamothrix bedoti		X											
Lumbriculidae													
Stylodrilus heringianus			X								X		
Lumbriculid						X				X	X	X	X
Enchytraeidae			X			X	X	X			X		
Naididae													
Nais variabilis	X	X	X	X			X	X	X	X	X	X	X
Nais bretscheri	X	X	X				X	X		X	X	X	
Nais simplex	X	X	X	X	X		X	X	X	X	X	X	X
Nais elinguis								X					

TABLE 84 . (continued).

Taxa	Station												
	PL11	PL24	PL25	PL31	PL32	PL41	PL42	PLX1	PLX2	PLX3	PL51	PL52	PL53
Nais communis								X		X			
Nais sp.								X		X			
Ophidonais serpentina	X	X	X										
Dero digitata		X											
Dero sp.			X					X					
Arcteonais lomondi		X								X			
Vejdovskyella intermedia		X			X								
Vejdovskyella comata										X			
Pristina foreli		X						X	X		X	X	X
Uncinais uncinata		X											
Piguetiella michiganensis									X				
Amphichaeta leydigii								X					
Stylaria lacustris			X	X		X	X	X	X	X	X	X	X
Stylaria fossularis								X		X	X	X	
Chaetogaster diaphanus		X	X				X	X	X	X	X	X	
Haemonais waldvogeli													
Hirudinea													
Glossiphoniidae													
Helobdella stagnalis			X	X		X	X	X	X	X	X	X	X
Glossiphonia complanata			X							X			
Malacostraca													
Amphipoda													
Gammaridae													
Gammarus sp.		X	X	X		X	X	X	X	X	X	X	X
Talitridae													
Hyalella azteca			X	X	X	X	X	X	X	X	X	X	X
Isopoda													
Asellidae													
Asellus sp.		X	X	X	X	X	X	X		X	X	X	X

TABLE 84. (continued).

Taxa	Station												
	PL11	PL24	PL25	PL31	PL32	PL41	PL42	PLX1	PLX2	PLX3	PL51	PL52	PL53
Lirceus sp.			X	X		X				X			X
Mollusca													
Pelecypoda													
Sphaeriidae													
Pisidium sp.		X		X			X		X	X		X	X
Sphaerium sp.								X	X				
Gastropoda													
Hydrobiidae													
Amnicola sp.		X	X	X		X		X	X	X	X	X	X
Bithynia tentaculata													
Valvatidae													
Valvata tricarrinata		X	X	X									
Physidae													
Physa sp.			X	X	X	X	X	X		X			X
Viviparidae													
Campeloma sp.			X										
Ancylidae													
Ferrisia sp.						X							
Planorbidae													
Menetus sp.							X						
Turbellaria		X	X	X	X		X	X				X	X
Hydracarina	X	X	X	X		X	X	X	X	X	X	X	X

TABLE 84. (continued).

Taxa	Station												
	PL11	PL24	PL25	PL31	PL32	PL41	PL42	PLX1	PLX2	PLX3	PL51	PL52	PL53
Coelenterata													
Hydrozoa													
Hydridae													
Hydra sp.		X	X				X	X		X	X		X
Insecta													
Lepidoptera			X	X		X	X	X		X		X	X
Coleoptera													
Haliplidae													
Peltodytes sp.			X										
Gyrinidae													
Dineutus sp.										X		X	
Gyrinus sp.												X	
Chrysomelidae													
Galerucella sp.												X	
Curculionidae									X				
Dytiscidae			X										
Hemiptera													
Notonectidae													
Notonecta sp.													
Pleidae													
Plea striola										X			
Ephemeroptera													
Caenidae													
Caenis sp.								X		X			X
Unknown						X		X					

TABLE 84. (continued).

Taxa	Station												
	PL11	PL24	PL25	PL31	PL32	PL41	PL42	PLX1	PLX2	PLX3	PL51	PL52	PL53
Odonata													
Coenagrionidae													
Enallagma sp.			X	X						X			
Trichoptera													
Hydroptilidae													
Agralea multipunctata								X					
Agralea sp.			X										
Oxyethira sp.								X					
Unknown			X										
Leptoceridae													
Ceraclea inconspicua			X										
Ceraclea transvera			X										
Ceraclea alagma						X		X		X		X	
Ceraclea sp.						X		X		X			X
Oecetis cenerascens						X	X	X					
Oecetis inconspicua				X		X							
Oecetis sp. A				X		X							
Oecetis sp. B				X									
Oecetis sp.								X	X	X	X	X	
Leptocerus americanus						X				X		X	
Leptocerus sp.										X			X
Leptocerid sp. A			X	X		X							
Setodes sp.			X										
Triaenodes sp.						X				X			
Nectopsyche sp.							X						
Phryganeidae													
Phryganea sp.			X										
Limnephilidae													
Limnephilus sp.			X										
Polycentropodidae													
Polycentropus sp.								X					X

TABLE 84. (continued).

Taxa	Station												
	PL11	PL24	PL25	PL31	PL32	PL41	PL42	PLX1	PLX2	PLX3	PL51	PL52	PL53
Unknown													X
Unknown trichopteran								X		X			X
Diptera													
Chironomidae													
Chironomus sp.	X	X	X	X	X	X	X	X	X	X	X	X	X
Chironomus plumosus-gr.	X					X							X
Chironomus semi-reductus-gr.							X						
Chironomus anthracinus-gr.						X				X		X	X
Cryptochironomus cfr. *fulvus*	X	X							X	X	X	X	X
Cryptochironomus cfr. *digitatus*					X		X						
Cryptochironomus sp.								X					
Polypedilum cfr. *scalaenum*		X							X				
Polypedilum cfr. *halterale*			X	X		X	X	X	X	X		X	X
Polypedilum cfr. *ophioides*				X				X		X		X	X
Polypedilum cfr. *flavus*													X
Paratendipes sp.		X							X	X			X
Microtendipes sp.		X	X			X		X	X	X	X	X	X
Dicrotendipes sp.		X	X	X	X	X	X	X	X	X	X	X	X
Glyptotendipes sp.								X		X			
Endochironomus sp.			X	X		X	X	X	X	X	X	X	X
Cladopelma sp.		X		X						X			
Phaenopsectra sp.						X		X		X			X
Paracladopelma cfr. *nereis*									X				
Paracladopelma cfr. *undine*									X				
Parachironomus cfr. *abortivus*			X	X		X	X	X	X	X	X	X	X
Parachironomus sp. 2		X				X		X		X	X		X
Parachironomus sp. 3			X					X		X		X	X
Parachironomus sp. 4										X		X	X
Saetheria cfr. *tylus*		X											

TABLE 84. (continued).

Taxa	Station												
	PL11	PL24	PL25	PL31	PL32	PL41	PL42	PLX1	PLX2	PLX3	PL51	PL52	PL53
Robackia cfr. demeijeri		X							X				
n. Goeldochironomus												X	
Psectrocladius sp. 1	X	X	X	X		X	X	X	X	X		X	X
Psectrocladius sp. 2			X	X		X	X	X		X		X	X
Thienemanniella sp.						X		X		X		X	X
Corynoneura sp.								X		X			
Cricotopus spp.	X	X	X	X	X	X	X	X	X	X	X	X	X
Nanocladius sp.			X	X		X	X	X		X	X	X	X
Pseudosmittia cfr. gracilis								X					X
Pseudosmittia sp.									X				
Orthocladiini sp. 1			X	X				X		X			
Orthocladiini sp. 2													X
Orthocladiini sp. 3													X
Orthocladiini sp. 4													X
Orthocladiini sp. 5													X
Monodiamesa cfr. depectinata									X				
Tanytarsus sp.		X		X		X		X		X		X	X
Cladotanytarsus sp.			X	X		X	X	X	X	X	X	X	X
Paratanytarsus sp.			X	X			X	X		X			X
Rheotanytarsus sp.			X							X			X
Micropsectra sp.													X
Procladius sp. 1	X	X	X	X	X	X	X	X	X	X		X	X
Procladius sp. 2			X					X					X
Procladius sp. 3												X	
Clinotanypus sp.						X	X	X		X		X	X
n. Guttipelopia								X		X		X	X
Thienemannimyia-gr.								X					
Ablabesmyia sp.		X	X	X		X	X	X		X		X	X
Tanypodini sp. 1								X					
Tanypodini sp. 2								X					
Tanypodini sp. 3			X					X					X
Ceratopogonidae			X	X		X	X	X	X	X	X	X	X
Ephydridae								X		X			

PL25 the greatest number of tubificid taxa (11) found at Pigeon Lake stations (Table 85). Tubificids comprised 91% of all animals at PL24. While most tubificids were immature (82% of tubificids), maximum abundances for L. hoffmeisteri and L. cervix were noted at this station when compared to other Pigeon Lake stations. In addition, greatest numbers of naidid, N. variabilis and the chironomid, Polypedilum cfr. scalaenum were found at PL24.

Transect 2 - Station PL25 --

The shallowest station on the second transect, PL25 (0.9 m), was selected to represent the benthic habitat from shallow depths and sloping bottom type. The bottom at PL25 was composed of submerged aquatic macrophytes, sand, silt and detritus.

Of the 69 taxa found at PL25 chironomids contained the greatest number of taxa with 21 (Table 85). Tubificids had 11 taxa present. Gastropods were represented by five taxa, the greatest number of gastropod taxa at any station in Pigeon Lake.

The second greatest number of total animals of all stations was found at PL25, (88687/m^2) (Table 82). Tubificids were most numerous (55%), followed by chironomids (13%), malacrustaceans (19%) and gastropods (6%) (Table 83). The following taxa occurred in maximum abundance at PL25 when compared to other stations in Pigeon Lake: the amphipod, Gammarus sp.; the isopod, Asellus sp.; the gastropod, Amnicola sp.; the naidids, in particular, Nais simplex; the turbellarians; and the chironomids, Psectrocladius sp. 1 and Nanocladius sp.

Transect 3 - Station PL31 --

Along the third transect PL3, the shallowest station was PL31 (0.9 m) which exhibited little, if any, slope in bottom topography. Samples collected were representative of benthos from shallow depths with little slope. The area sampled was densely covered with submerged and some emergent aquatic macrophytes. Bottom material was sand, silt and detritus. There were 42 benthic taxa identified from PL31 (Table 84). Chironomid taxa were the most prevalent group with 18.

Mean abundance of total animals at PL31 (35739/m^2) was the fourth highest noted in Pigeon Lake (Table 82). Many of the following taxa attained their maximum abundance at PL31: the chironomids, Cricotopus spp., Endochironomus sp., Dicrotendipes sp., Cladotanytarsus sp., Psectrocladius sp. 2, and Parachironomus cfr. abortivus; the amphipod, Hyalella azteca; and the leech, H. stagnalis. Dominant groups were the chironomids (56% of total animals) and the malacrustaceans (29% of total animals) (Table 83). The two most abundant genera at PL31 were Cricotopus spp. (23% of total animals) and H. azteca (19% of total

TABLE 85. Number of benthos taxa collected from each station of Pigeon Lake in the vicinity of the J. H. Campbell Plant, June 1977.

Taxa	Station													
	PL11	PL24	PL25	PL31	PL32	PL41	PL42	PLX1	PLX2	PLX3	PL51	PL52	PL53	Over All
Gastropoda		2	5	3	1	4	2	2	1	3	2	3	2	7
Hirudinea			2	1		1	1	1	1	2	1	1	1	2
Chironomidae	5	15	21	18	4	20	14	32	18	30	11	23	39	56
Naididae	4	10	8	3	2	1	5	12	6	10	7	7	7	20
Tubificidae	9	11	11	3	1	3	1	3	1	4	3	2	3	16
Ephemeroptera						1		2		1		1	1	2
Trichoptera			8	4		8	2	8	1	8	1	3	5	24
Odonata			1	1						1				1
Hemiptera										1		1		2
Coleoptera			2						1	1		3		5
Other	1	6	11	9	3	9	10	11	6	11	9	9	11	15
Total	19	44	69	42	11	47	35	71	35	72	34	53	69	150

animals).

Transect 3 - Station PL32 --

The second station selected on the third transect was PL32 (3.7 m). This station was assumed to be representative of the benthic habitat occurring near the deeper end of a sloping contour. There were a few submerged aquatic macrophytes present. Substrate taken consisted primarily of detritus.

Compared with all other sample sites in Pigeon Lake, the lowest number of taxa (11) was found at PL32 (Table 85). The group with the most taxa present was the chironomids which had four taxa.

Tubificids (49% of total animals) and chironomids (35% of total animals) were the major constituents of the total animal mean abundance of 11818/m^2 at PL32 (Table 82). The only tubificid present aside from immatures was A. pluriseta. Both Chironomus spp. and Procladius sp. 1 at PL32 occurred in the largest numbers noted in Pigeon Lake. Procladius sp. 1 occurred in only one of the three samples taken at PL32.

Transect 4 - Station PL41 --

Along the fourth transect the shallowest station selected was PL41 (0.9 m). The area sampled consisted of submerged and emergent macrophytic plants and sand, silt and detrital substrates. Being similar to PL31, samples from PL41 were representative of benthic habitats from shallow depths with a flat bottom topography.

There were 47 taxa identified at PL41. Chironomids had the largest number of taxa with 20. Trichopterans had the next largest number of taxa with eight (Table 85).

Station PL41 had an average abundance of 19162 animals/m^2 (Table 82). The benthic community at PL41 was dominated by the second greatest number of Gammarus sp. found in Pigeon Lake. The major components of the benthic community were malacrustaceans (46% of total animals) and chironomids (39% of total animals) (Table 83). Dicrotendipes sp. and Cricotopus spp., were the two most abundant chironomid taxa. The isopod, Lirceus sp. was found in the highest concentration of any station sampled in Pigeon Lake. The most numerous trichopterans were the leptocerids, Ceraclea sp. and Oecetis spp.

Transect 4 - Station PL42 --

The second station selected along the fourth transect was PL42. The 1.4 m deep PL42 was representative of benthic habitat in shallow depths with a flat bottom topography on the south side of Pigeon Lake.

Station PL42 was similar to PL41 and PL31. Submerged and emergent aquatic macrophytes and substrates of sand, silt and detritus were primary constituents of the benthic habitat type.

There were 35 taxa identified from the sample taken at PL42. These 35 taxa were composed primarily of chironomids (14) and naidids (5) (Tables 84 and 85).

Abundance of individual taxa at PL42 tended to be more evenly spread across taxa than that found at other stations in Pigeon Lake. The most numerous genus, Cricotopus spp., comprised only 11% of the total animal abundance of $10249/m^2$ (Table 82). However, chironomids as a group accounted for 50% of the animals found at PL42 while naidids and malacrustaceans accounted for 13% and 12%, respectively (Table 83). Gammarus sp. was the most numerous malacrustacean.

Pigeon Lake - Eastern Basin

Transect 5 - Station PL51 --

The fifth transect was established at the eastern end of the eastern basin of Pigeon Lake. The first station selected (PL51) was near the south shore in 0.5 m of water. The second station chosen (PL52) was near mid-lake where depth was 0.6 m . Both stations were selected as representative of benthic habitats at different distances from shore. Stations PL51 and PL52 were comprised primarily of detritus and some emergent and submerged aquatic macrophytes. Presence of a thick layer of organic detritus covering the entire bottom of the lake in this area was the most notable physical characteristic. As a result, samples contained no sand or material other than peat and macrophytes.

The 34 taxa identified from PL51 was the lowest total found in the eastern basin of Pigeon Lake. Chironomids (11 taxa) and naidids (7 taxa) contributed the most to the species diversity noted at PL51 (Tables 84 and 85).

Of the average 4965 animals/m^2 found at PL51, 40% were malacrustaceans which were dominated by Gammarus sp. (31% of total animals) (Tables 82 and 83). Chironomids and tubificids accounted for 22% and 13% of the animals found at PL51, respectively. The chironomid, Cricotopus spp., and the tubificid, L. hoffmeisteri, were the most numerous taxa with respect to their particular groups. When compared to other sample sites in Pigeon Lake, gastropods at PL51 comprised the largest percentage of total animals (8%) observed.

Transect 5 - Station PL52 --

From the samples taken at PL52 a total of 53 taxa were

distinguished. Only chironomids (23 taxa) and naidids (7 taxa) contributed significant numbers to the total number of taxa found (Tables 84 and 85).

At PL52 leeches comprised the greatest percentage (14%) of total animals of any station in Pigeon Lake. However, of a mean abundance of animals of 5018/m^2 at PL52, the major components were chironomids (39%) and malacrustaceans (28%) (Tables 82 and 83). The dominant chironomid was *Cricotopus* spp. *Asellus* sp. was the single most abundant genus (14% of total animals). Station PL52 was similar to PL42 in that abundance of animals tended to be more evenly distributed over taxa. No single genus comprised a vast proportion of the total abundance.

Transect 5 - Station PL53 --

The third station along the fifth transect was PL53 (0.6 m). Station PL53 was positioned within 3 m of shore as an example of a benthic, nearshore habitat in an area that may be affected by wave action. Substrates in this area consisted of sand, silt and detritus. Small amounts of submerged aquatic macrophytes were present.

Although not very abundant, trichopterans contributed five taxa to the 69 taxa identified at PL53. The largest number of chironomid taxa (39) of any station in Pigeon Lake was present at PL53. There were also seven naidid taxa present (Tables 84 and 85).

At PL53 the mean abundance of animals was 10502/m^2 (Table 83). Malacrustaceans (48% of total animals) were the most numerous form present. The most abundant genera at PL53 were the malacrustaceans, *Asellus* sp. (26% of total animals) and *Gammarus* sp. (13% of total animals). Chironomids comprised 32% of the total animal abundance with *Procladius* sp. 1 being the most abundant chironomid (Table 83).

Transect 6 - Station PLX1 --

The sixth transect (PLX) was located along the western end of the eastern basin of Pigeon Lake. Station PLX1 (0.9 m) was the first station on the sixth transect. The benthic habitat type consisted of luxuriant growths of submerged and emergent aquatic macrophytes and a thick layer of organic detritus covering the bottom. The outer edges of the area sampled were in close proximity to a lotic environment. The lotic condition was caused by the flow of water from the eastern to the western basin through a culvert under the road that separates the two basins of Pigeon Lake.

The second largest number of taxa (71) in Pigeon Lake was found at PLX1. Of these, 32 were chironomid taxa. Twelve taxa of naidids were present at PLX1, the greatest number of taxa present at any station

(Tables 84 and 85).

Considering eastern basin stations, the second greatest abundance of animals was found at PLX1 ($14430/m^2$). Chironomids (54% of total animals) and malacrustaceans (26% of total animals) were the most numerous groups present (Tables 82 and 83). The chironomid, Cricotopus spp., was the most abundant genus at PLX1. Gammarus sp. and Asellus sp. comprised 15% and 8% of the total animals, respectively. Hydracarinids were more abundant at PLX1 than at any other station in Pigeon Lake. Trichopterans had eight taxa represented. The most numerous trichopterans were Polycentropus sp. and Agraylea multipunctata.

Transect 6 - Station PLX2 --

The second station along the sixth transect was PLX2. Station PLX2 (1.5 m) was sampled as representative of a benthic habitat type characterized as lotic, with medium to coarse sand and small amounts of detritus. There were no aquatic macrophytes growing in this area.

There were 35 taxa identified from the samples collected at PLX2. Chironomids contributed 18 taxa and naidids six taxa to the total taxa observed (Tables 84 and 85).

Station PLX2 contained the lowest number of animals ($1954/m^2$) of any station in Pigeon Lake (Table 82). The dominant taxonomic groups were chironomids (44% of total animals), naidids (25% of total animals) and sphaeriids (9% of total animals). Station PLX2 had the largest percentage composition of naidids of any station sampled in Pigeon Lake. The most abundant taxa were the chironomid, Chironomus spp.; the naidids, N. simplex and N. variabilis; and the sphaeriid, Pisidium spp. Also present but in low numbers were the chironomids, Robackia cfr. demeijerei and P. cfr. scalaenum and the naidid, Piguetiella michiganensis (only station where it occurred).

Transect 6 - Station PLX3 --

Along the sixth transect, the third sample site was PLX3 (0.5 m). Being similar to PLX1, PLX3 had a luxuriant growth of submerged and emergent aquatic macrophytes. The substrate consisted of a thick layer of organic detritus

The 72 taxa identified at PLX3 was the largest number found at any station in Pigeon Lake. The groups contributing most to the total number of taxa observed were chironomids (30), naidids (10) and trichopterans (8)(Tables 84 and 85).

The greatest number of animals in the eastern basin was found in the samples from PLX3 ($24294/m^2$) (Table 82). Although chironomids

accounted for 41% of the animals at PLX3, malacrustaceans, dominated by H. azteca (16% of total animals), Asellus sp. (10% of total animals) and Gammarus sp. (9% of total animals), comprised 35% of the animals at PLX3. The single most abundant genus at PLX3 was Cricotopus spp. which accounted for 17% of the animals. Lepidopterans were more abundant at PLX3 than at any other station in Pigeon Lake. Leptocerus americanus and Leptocerus sp. were the most numerous trichopterans present.

Pigeon Lake - Discussion

One of the primary considerations when sampling any environment is an awareness of available habitats. Ideally each habitat would be sampled routinely in the course of a study. In Pigeon Lake adequate sampling of both substrate types and aquatic macrophyte taxa are necessary to accurately define the benthos present. For example, in another study, the only occurrence of Corynoneura scutellata was within the petioles of Nuphar (Ramcharan and Paterson 1978). The same authors found two taxa of chironomids segregated from a third only in their choice of rounded as opposed to angular, coarse detritus.

In the present study detail in habitat selection had to be at the general level. Constraints dictated that substrate and aquatic macrophytes be combined. However, sample sites were located with respect to the topographical profile; i.e., littoral, sublittoral and deep-water zones of Pigeon Lake. Since transects were established across the profile, varying habitat types were encompassed and distinctions between stations can be made within Pigeon Lake based on these rough approximations.

Sublittoral and deep-water (profundal) habitats occur only in the central and western end of the western basin of Pigeon Lake. The deep water habitat was dominated by eutrophic, indicator organisms; e.g., L. cervix, T. tubifex, P. m. multisetosus, P. m. longidentis, Chironomus spp. and Procladius sp. The sublittoral zone had a more variable substrate than the deep-water habitat. Quite possibly the sublittoral habitat was exposed to currents that kept detrital-laden sand from becoming too silty to support taxa like S. cfr. tylus, R. demeijerei, P. cfr. scalaenum and Pisidium spp. These taxa were present at two other stations, PLX2 and PL53, which experienced currents or waves and had basically sandy substrates. The same taxa above occurred in the littoral area of Lake Michigan at a depth of 3-12 m. Bottom type and current effects in Pigeon Lake were similar to that observed in Lake Michigan at 3-12 m, i.e., slightly silty, wave-washed sand coupled with alongshore currents.

Other areas of the sublittoral had sediments similar to the deep water substrates which may be the result of depressions on the bottom or eddying of currents. The sandy sublittoral habitat type supported a

diverse assortment of benthos, including mostly mesotrophic indicator tubificids like A. pluriseta and P. vejdovskyi while the silted sublittoral habitat supported a sparse assortment of benthos and mostly eutrophic indicator tubificids like L. hoffmeisteri, L. cervix and T. tubifex.

Littoral area of Pigeon Lake provided the only habitat type allowing direct comparison between the western and eastern basins. The littoral area in the western half of the western basin was small when compared with either the eastern half of the western basin or the eastern basin. Since PL32 (deep end of a slope), PLX2 and PL53 (sandy environment with current), and PL51 and PL52 (peat with flat bottom) were atypical of the littoral zone of Pigeon Lake, stations PL25, PL31, PL41, PL42, PLX1 and PLX3 formed the core stations from which direct comparisons of data between the western and eastern basins were made.

Comparisons among the littoral area stations (PL25, PL31, PL41, PL42, PLX1 and PLX3) must take into account habitat type differences between stations. Stations PL31, PL41, PL24, PLX1 and PLX3 had similar habitat types (much vegetation, sand, silt and organic, detrital substrates). All of these littoral station samples contained primarily chironomids and malacrustaceans (62-85% of total animals). Among stations which had considerable vegetation present, maximum abundance occurred for the following benthic forms: H. azteca, Lirceus sp., many chironomids including Cricotopus spp., H. stagnalis and hydracarinids. Althouth specific differences in absolute abundances of given taxa varied from station to station in the littoral area, overall structure of the community of benthic macroinvertebrates remained relatively constant for stations PL31, PL41, PL42, PLX1 and PLX3.

The littoral zone in the area of the lake in the vicinity of PL25 was much narrower and eroding than that found in areas of Pigeon Lake east of the intake channel. Results from sampling the littoral zone in the western end of the western basin of Pigeon Lake showed that habitat was substantially different from that of the other littoral zone stations mentioned previously. Differences in species composition observed between PL25 and PL31, etc. were likely due to habitat differences.

Malacrustaceans and chironomids at PL25 (littoral zone - western basin) comprised only 32% of the total animal fauna while the major constituent there was tubificids (55% of total animals). However, even though malacrustaceans occurred in low percentages at PL25, Gammarus sp. and Asellus sp. occurred at their maximum abundance. Although there was ample vegetation at PL25, less vegetation was present compared with other littoral stations. As a result, it is suspected that the efficiency of the Ponar in obtaining a sample, not only of the vegetation but of the substrates, may have been increased at PL25. For

the sake of comparison, assuming tubificids were the major constituents of the substrate, tubificid total was removed from the total animals at PL25, leaving malacrustaceans which comprised 40% and chironomids 30% of the total remaining animal population. Thus, PL25 compared favorably (70% malacrustaceans and chironomids) with other littoral-zone stations (PL31, etc.). Therefore, although PL25 appeared to be substantially different from other littoral-zone stations, suspected increased efficiency of the Ponar may have resulted in the differences noted which were mostly increased numbers of tubificids.

The major differences observed in numbers and species of benthos between the stations were caused mostly by habitat type. Since the Ponar appeared to sample the substrate below vegetation inefficiently and did not effectively sample fast-swimming organisms; e.g., ephemeropterans, coleopterans and hemipterans, use of a sampling device or devices other than the Ponar may have more efficiently sampled the organisms and separate habitats.

Pigeon Lake - Summary

In Pigeon Lake 7 of 13 stations sampled had a mean abundance of total animals that fell within the range 10000-50000 animals/m^2. Three stations (PL11, PL24 and Pl 25) exceeded 50000 animals/m^2 and three stations had fewer than 10000 animals/m^2 (PL51, PL52 and PLX2). While most sample sites were dominated numerically by chironomids (32-56% of the total animals present), four stations (PL11, PL24, PL25 and PL32) were dominated by tubificids (49-97% of total animals present) and one station (PL51) was dominated by *Gammarus* sp. If malacrustaceans (Amphipoda and Isopoda) were pooled, then three stations (PL41, PL51 and PL53) were dominated numerically by this group.

The most abundant chironomids in Pigeon Lake were the orthoclads, *Cricotopus* spp. Aside from unidentified immature tubificids, the identifiable tubificids comprising the greatest percentage of the total animal abundance in Pigeon Lake were *Aulodrilus pluriseta* and *Limnodrilus hoffmeisteri*. Other major components of the benthos in Pigeon Lake were the naidid, *Nais variabilis*; the leech, *Helobdella stagnalis*; the gastropod, *Amnicola* sp.; the sphaeriids, *Pisidium* spp.; and the trichopteran family, Leptoceridae.

There were 150 taxa identified from Pigeon Lake. While most stations (7 of 13) had between 30-60 taxa present, four stations (PL25, PLX1, PLX3 and PL53) had more than 60 taxa present and two stations (PL11 and PL32) had less than 30. Chironomids were the most diverse group present with 56 identifiably different forms, followed by trichopterans (24), naidids (20), tubificids (16), gastropods (7) and miscellaneous others (27).

The species list would be much greater had chironomids been identified beyond the genus level, which was not possible with present knowledge. In particular, the genus Cricotopus probably consisted of 10 or more different forms. However, since Cricotopus spp. were generally quite small and occurred in great quantities, taxonomic treatment could not be complete without further procedures beyond the scope of the study (i.e., rearing larva to adult stages). Finally, swift moving taxa would have increased the list of taxa present in Pigeon Lake and possibly at each station had another mode(s) of collection been used. Nevertheless, the study was able to collect a large number of taxa and produce quantitative results that will provide baseline data for future studies.

SCUBA OBSERVATIONS

Introduction

The following represents a compendium of physical and biological information obtained from seven SCUBA dives in Lake Michigan in the vicinity of the J. H. Campbell Plant 9 August 1977. Time of each dive and direction swum are presented in Table 86, while subsequent information details physical and biological characteristics associated with each station within a given transect. Black and white pictures were also taken along each transect documenting bottom configuration and any unique objects. These prints are available from the Great Lakes Research Division or Consumers Power, Environmental Services Division, Jackson, Michigan. Diving was performed to document unique fish-spawning areas or substrates prior to construction of the intake and discharge structures and to evaluate some existing physical, limnological and biological conditions in the lake. We also noted unique features such as irregular lake-bottom terrain, areas of locally increased turbidity and presence of rooted aquatic macrophytes. Use of SCUBA permits direct observation and hand-sampling of an area; data obtained may supplement or be correlated with data obtained during other (primarily mechanical) sampling efforts in the study area. Observations were made by John A. Dorr III, Gregory G. Godun and James A. Wojcik; all divers were aquatic biologists experienced in underwater survey, sampling and observational techniques.

Description of each SCUBA Dive

Dive No. 1

Diving Team: Dorr, Godun
Location: future discharge canal transect (Fig. 6)
Date: 9 August 1977
Time: 1540-1725
Duration: 105 min
Estimated length of transect: 1000 m W to E
400 m N following 6 m contour
Depth range: 12.2-5.2 m
Secchi disc: 3.0 m
Water temperature: 21.5 C surface, 21.5 C bottom
same for all stations
Air temperature: 26 C
Cloud cover: overcast
Wind: S, 8-16 km/hr
Seas: SW, wave height 0.3 m
Weather: rain

TABLE 86. Summary of survey SCUBA dives performed in eastern Lake Michigan near the J. H. Campbell Plant, 9-10 August 1977. Times given (EST) are times of observation at each station.

Date	Time	Dive No.	Station Number	Depth (m)	Team
9 Aug	1544	1	1	12.2	Dorr, Godun
	1548		2	12.2	
	1557		3	11.3	
	1605		4	10.4	
	1616		5	8.5	
	1646		6	7.9	
	1655		7	7.0	
	1704		8	6.1	
			(direction shift, from E to N)		
	1710		9	5.2	
	1720		10	5.5	
9 Aug	1805	2	1	10.4	Dorr, Wojik
	1835		2	9.5	
	1845		3	8.5	
	1851		4	7.0	
	1856		5	6.1	
			(direction shift, from E to S)		
	1904		6	5.8	
	1912		7	6.1	
	1917		8	6.1	
10 Aug	1201	3	1	5.2	Dorr, Godun
	1219		2	7.6	
	1230		3	9.1	
	1240		4	10.7	
	1246		5	11.6	
	1316		6	12.5	
	1320		7	12.8	
			(direction shift, from W to S)		
	1341		8	11.9	
10 Aug	1358	4	1	8.5	Dorr, Wojcik
	1410		2	8.8	
10 Aug	1431	5	1	7.6	Dorr, Wojcik
	1437		2	7.6	
10 Aug	1505	6	1	12.2	Dorr, Wojcik
	1506		2	11.0	
	1515		3	10.7	
10 Aug	1604	7	1	12.2	Dorr, Wojcik
	1606		2	11.3	
	1614		3	11.6	
			(direction shift, from N to E)		
	1615		4	10.7	
	1622		5	11.0	
			(direction shift, from E to N)		
	1644		6	9.1	
	1645		7	8.8	
	1648		8	8.8	

Station 1 - Time: 1544
Depth: 12.2 m
Bottom: fine sand
Organic detritus: few mm floc
Biological notes: none

Station 2 - Time: 1548
Depth: 12.2 m
Bottom: fine sand
Organic detritus: few mm floc
Biological notes: none

Station 3 - Time: 1557
Depth: 11.3 m
Bottom: fine sand
Organic detritus: few mm floc
Biological notes: none

Station 4 - Time: 1605
Depth: 10.4 m
Bottom: sand
Organic detritus: few mm floc
Biological notes: none

Station 5 - Time: 1616
Depth: 8.5 m
Bottom: sand
Organic detritus: few mm floc
Biological notes: none

Station 6 - Time: 1646
Depth: 7.9 m
Bottom: sand
Organic detritus: few mm floc
Biological notes: none

Station 7 - Time: 1655
Depth: 7.0 m
Bottom: coarse sand, ripple marks larger than those observed at deeper stations
Organic detritus: fine silt between ripple marks (several mm thick)

Biological notes: none

Station 8 - Time: 1704
Depth: 6.1 m
Bottom: coarse sand
Organic detritus: fine silt between ripple marks (several mm thick)
Biological notes: one dead crayfish, few clumps of aquatic macrophyte *Myriophyllum* sp. (10-30 mm diameter)

At this point in the transect (station 8), divers turned 90 degrees and swam north parallel to shore for approximately 400 m.

Station 9 - Time: 1710
Depth: 5.2 m
Bottom: coarse sand
Organic detritus: none observed
Biological notes: none

Station 10- Time: 1720
Depth: 5.5 m.
Bottom: fine sand
Organic detritus: none observed
Biological notes: none

The following between-station observations were made:

1) Young-of-the-year (YOY) alewife 20-30 mm long were abundant. Numerous schools of 10-100 fish per school were seen. Many fish were observed darting and "snapping" (not coughing) which was interpreted to be feeding behavior.

2) Loose clumps of *Myriophyllum* sp. were present in trace amounts at most stations 6 m or deeper. Clumps were small (10-30 mm diameter) and appeared randomly distributed.

3) Floc (fine organic detritus and sediment), a few milimeters thick, was observed at all stations, except stations 9 and 10. Where ripple marks were large, floc concentrated in troughs.

4) There was a distinct shift in sand grain size from fine to coarse (prodeeding shoreward) at approximately 7 m. In addition, ripple marks which were previously smaller and

asymmetric at deeper stations became larger (1-2 cm trough-to-crest, 15-20 cm crest-to-crest, 1-2 m long) and more symmetric.

Dive No. 2

Diving Team: Dorr, Wojcik
Location: south reference transect (Fig. 6)
Date: 9 August 1977
Time: 1805-1917
Duration: 72 min
Estimated length of transect: 800 m W to E
400 m N following 6 m contour
Depth range: 10.4-5.8 m
Secchi disc: 3.5 m
Water temperature: 21.0 C surface, 21.0 C bottom
same for all stations
Air temperature: 26 C
Cloud cover: overcast
Wind: S, 0-8 km/hr
Seas: SW, wave height 0.2 m
Weather: rain ending, skies clearing

Station 1 - Time: 1805
Depth: 10.5 m
Bottom: fine sand
Organic detritus: few mm floc
Biological notes: snails (*Valvata* sp.) abundant

Station 2 - Time: 1835
Depth: 9.5 m
Bottom: fine sand
Organic detritus: few mm floc
Biological notes: snails (*Valvata* sp.) abundant

Station 3 - Time: 1845
Depth: 8.5 m
Bottom: fine sand
Organic detritus: few mm floc
Biological notes: snails (*Valvata* sp.) not as abundant as stations 1 and 2

Station 4 - Time: 1851
Depth: 7.0 m
Bottom: sand, less fine than stations 1 and 3
Organic detritus: few mm floc
Biological notes: snails not observed

Station 5 - Time: 1856
Depth: 6.1 m
Bottom: coarse sand
Organic detritus: little
Biological notes: none

At this point (station 5) divers turned 90 degrees and swam south parallel to shore for approximately 400 m.

Station 6 - Time: 1904
Depth: 5.8 m
Bottom: coarse sand
Organic detritus: little
Biological notes: none

Station 7 - Time: 1912
Depth: 6.1 m
Bottom: coarse sand
Organic detritus: little
Biological notes: none

Station 8 - Time: 1917
Depth: 6.1 m
Bottom: coarse sand
Organic detritus: none
Biological notes: none

The following between-station observations were made:

1) YOY alewife were abundant; schooling was apparent.
2) Small loose clumps of *Myriophyllum* sp. were occasionally encountered.
3) Floc layer, bottom composition and zonation and ripple mark pattern paralleled that observed during Dive No. 1.
4) Occurrence and abundance of snails (*Valvata* sp.; stations 1 and 3) were unique to this dive.

Dive No. 3

Diving Team: Dorr, Godun
Location: future intake transect (Fig. 6)
Date: 10 August 1977
Time: 1201-1341
Duration: 100 min
Estimated length of transect: 1000 m E to W
400 m N to S
Depth range: 5.2-12.8 m
Secchi disc: 4.0 m
Water temperature: 25 C
Air temperature: 26 C
Cloud cover: partly cloudy
Wind: SSW, 8-16 km/hr
Seas: SW, wave height 0.3-0.5 m
Weather: clear

Station 1 - Time: 1201
Depth: 5.2 m
Bottom: medium-fine sand, ripple marks 5-7 cm high, 10 cm apart
Organic detritus: 1-3 mm of floc in ripple mark troughs
Biological notes: one alewife (25 mm) seen swimming near bottom

Station 2 - Time: 1219
Depth: 7.6 m
Bottom: medium-fine sand, ripple marks
Organic detritus: more floc than station 1
Biological notes: none

Station 3 - Time: 1230
Depth: 9.1 m
Bottom: medium-fine sand, ripple marks smaller, less pronounced, closer together (5-7 cm) than stations 1 and 2
Organic detritus: floc layer 4 mm thick
Biological notes: many schools of small alewife (approximately 25 mm) swimming approximately 0.3 m from bottom, 10-20 fish/school

Station 4 - Time: 1240
Depth: 10.7 m
Bottom: medium-fine sand
Organic detritus: floc layer 4 mm thick
Biological notes: numerous snail tracks observed

Station 5 - Time: 1246
Depth: 11.6 m
Bottom: medium-fine sand
Organic detritus: floc layer less thick than previous stations
Biological notes: none

Station 6 - Time: 1316
Depth: 12.5 m
Bottom: fine sand, ripple marks indistinct
Organic detritus: thin (1-2 mm) layer of floc
Biological notes: log observed, approximately 10 cm diameter, 2-3 m in length

Station 7 - Time: 1320
Depth: 12.8 m
Bottom: fine sand
Organic detritus: fine layer of floc
Biological notes: none

Station 8 - Time: 1341
Depth: 11.9 m
Bottom: fine sand
Organic detritus: fine layer of floc
Biological notes: none

Between-station observations related to change in bottom composition, ripple mark pattern and accumulation of organic detritus paralleled those taken at previous transects (dive nos. 1 and 2). During this transect there was a marked improvement in horizontal visibility from the 5.2 m station (visibility less than 2 m) to the 10.7 m station (visibility 3 m), despite increasing depth.

Dive No. 4

Diving Team: Dorr, Wojcik

Location: 6 m contour perpendicular to future intake transect (Fig. 6)
Date: 10 August 1977
Time: 1358-1415
Duration: 17 min
Estimated length of transect: 200 m S to N
Depth range: 8.5-8.8 m
Secchi disc: 4.0 m
Water temperature: 21.0 C surface and bottom
same for all stations
Air temperature: 25 C
Cloud cover: partly cloudy
Wind: SSW, 8-16 km/hr
Seas: SW, wave height 0.3-0.5 m
Weather: clear

Station 1 - Time: 1358
Depth: 8.5 m
Bottom: fine sand
Organic detritus: floc layer relatively thick (3-5 mm)
Biological notes: one tree branch observed

Station 2 - Time: 1410
Depth: 8.8 m
Bottom: fine sand, ripple marks 5-7 cm high, 7-10 cm apart
Organic detritus: floc layer relatively thick (3-5 mm)
Biological notes: none

Dive No. 5

Diving Team: Dorr, Wojcik
Location: 9 m contour, perpendicular to future discharge transect (Fig. 6)
Date: 10 August 1977
Time: 1431-1440
Duration: 10 min
Estimated length of transect: 200 m N to S
Depth range: 7.6 m
Secchi disc: 4.0 m
Water temperature: 21.0 C surface and bottom
same for all stations
Air temperature: 25 C

Cloud cover: partly cloudy
Wind: SSW, 8-16 km/hr
Seas: SW, wave height 0.3-0.5 m
Weather: clear

Station 1 - Time: 1431
Depth: 7.6 m
Bottom: fine sand
Organic detritus: thin layer of floc
Biological notes: none

Station 2 - Time: 1437
Depth: 7.6 m
Bottom: fine sand
Organic detritus: thin layer of floc
Biological notes: none

Dive No. 6

Diving Team: Dorr, Wojcik
Location: 12 m contour, perpendicular to future discharge transect (Fig. 6)
Date: 10 August 1977
Time: 1505-1520
Duration: 15 min
Estimated length of transect: 200 m S to N
Depth range: 12.2-10.7 m
Secchi disc: 4.0 m
Water temperature: 21.0 C surface and bottom same for all stations
Air temperature: 25 C
Cloud cover: partly cloudy
Wind: SSW, 8-16 km/hr
Seas: SW, wave height 0.3-0.5 m
Weather: clear

Station 1 - Time: 1505
Depth: 12.2 m
Bottom: fine sand
Organic detritus: 1-3 mm floc
Biological notes: none

Station 2 - Time: 1506

Depth: 11.3 m
Bottom: fine sand
Organic detritus: 1-3 mm floc
Biological notes: none

Station 3 - Time: 1515
Depth: 11.6 m
Bottom: fine sand
Organic detritus: slightly more floc than stations 1 and 2, turbidity higher (visibility less than 1.2 m)

Biological notes: one large (10 cm diameter) clump of aquatic macrophyte (<u>Myriophyllum</u> sp.) observed

Slight increase in turbidity noted from stations 1 to 3.

Dive No. 7

Diving Team: Dorr, Wojcik
Location: 12 m contour at reference location south of Campbell Plant (Fig. 6)
Date: 10 August 1977
Time: 1604-1650
Duration: 46 min
Estimated length of transect: 200 m S to N
500 m W to E
200 m W to N
Depth range: 12.2-8.8 m
Secchi disc: 4.0 m
Water temperature: 21.0 C surface and bottom same for all stations
Air temperature: 25 C
Cloud cover: partly cloudy
Wind: SSW, 8-16 km/hr
Seas: SW, wave height 0.3-0.5 m
Weather: clear

Station 1 - Time: 1604
Depth: 12.2 m
Bottom: fine sand
Organic detritus: 1-3 mm floc

Biological notes: none

Station 2 - Time: 1606
Depth: 11.3 m
Bottom: fine sand
Organic detritus: 1-3 mm floc
Biological notes: none

Station 3 - Time: 1614
Depth: 11.6 m
Bottom: fine sand
Organic detritus: 1-3 mm floc
Biological notes: snails (*Valvata* sp.) abundant

At this point (station 3) in the transect, divers turned 90 degrees and swam east (shoreward) for approximately 500 m.

Station 4 - Time: 1615
Depth: 10.7 m
Bottom: fine sand
Organic detritus: 1-3 mm floc
Biological notes: snails (*Valvata* sp.) abundant

Station 5 - Time: 1622
Depth: 11.0 m
Bottom: fine sand
Organic detritus: 1-3 mm floc
Biological notes: snail less abundant

At this point (station 5) in the transect, divers turned 90 degrees and swam from south to north for approximately 200 m.

Station 6 - Time: 1644
Depth: 9.1 m
Bottom: fine sand
Organic detritus: 1-3 mm floc
Biological notes: snails (*Valvata* sp.) numerous

Station 7 - Time: 1645
Depth: 8.8 m
Bottom: fine sand

Organic detritus: 1-3 mm floc
Biological notes: snails (*Valvata* sp.) numerous

Station 8 - Time: 1648
Depth: 8.8 m
Bottom: fine sand
Organic detritus: 1-3 mm floc
Biological notes: snails (*Valvata* sp.) numerous

Bottom composition was similar to that found at previous transects. Snails (*Valvata* sp.) were first observed outside station 3 (11.6 m) and were most abundant at stations 3 and 4 (11.6-10.7 m). Snail density decreased at stations 5-7 (11.0-8.8 m), relative to stations 3 and 4.

Summary

Scuba observations at each of the transects swum in the vicinity of the Campbell Plant on 9-10 August 1977 are summarized below in three categories: physical, limnological and biological.

Physical observations - -

(1) Bottom sediments in the vicinity of the transects swum consisted exclusively of sand, primarily fine-grained and of homogeneous size.

(2) In all instances, grain size of substrate increased with decreasing depth. A distinct transition zone (from fine to coarse sand) occurred at approximately the 7.5 m contour. Coarse sand and occasional pebbles extended from the 7.5 to the 6.0 m contour.

(3) A few areas of fine sand overlain by several millimeters of silt were encountered, primarily offshore from the 7.5 m contour. Silt was often concentrated in troughs of ripple marks.

(4) Substrate was entirely shifting-sand; rocks, gravel, clay and heavy silt were not encountered.

(5) Ripple marks at stations deeper than 7.5 m were generally small (2-5 cm trough-to-crest, 10-20 cm crest-to-crest and 30-60 cm long) and were not consistently developed from any specific direction. Larger and more pronounced ripple marks were observed from the 7.5 m contour shoreward.

(6) Bottom profile was flat and even; rises, depressions and sudden drop-offs were not encountered.

Limnological observations - -

(1) Slight variations (1-4 C) in water temperature were noted between locations. Highest water temperature recorded (25 C) was at the 5.2 m station in front of the jetties, and may have resulted from heated discharge water flowing south and being deflected offshore by the jetties. Vertical temperature stratification was not encountered.

(2) Secchi disc readings remained relatively constant ranging from 3.0 - 4.0 m. Generally, horizontal visibility along the bottom increased with decreasing depth as a function of increased light penetration. An exception occurred at the jetties (dive no. 3) where visibility increased from 2 m to 3 m despite increasing depth. No explanation of this occurrence was apparent.

(3) Suspended material was finely particulate in nature; composition of particulate matter was indiscernible to the unaided eye.

Biological observations - -

(1) Loose algae were not found.

(2) Macroscopic accumulations of periphyton were not observed except when an occasional large substrate (e.g., tree branch, rock, trash) was encountered.

(3) Small (2-10 cm diameter) clumps of loose aquatic plant material were infrequently observed. A consistent pattern of occurrence was not determined but clumps appeared to occur more frequently at deeper (6-12 m) stations. Composition of clumps appeared to be similar. One sample was collected and found to be primarily the aquatic vascular plant Myriophyllum sp. and associated algae.

(4) Several tree branches and one log were encountered at isolated locations.

(5) Small aggregates (1 cm thick - approximately one handful in volume) of organic debris were occasionally observed. Debris was composed primarily of unidentified decayed material and pieces of terrestrial vegetation. Material was concentrated in troughs of ripple marks. Organic debris and floc were more abundant offshore from the 7.5 m contour; very little was observed at shallow (6.0 m) stations.

(6) Thousands of snails (Valvata sp.) were seen on the bottom within the south reference transects (dive nos. 2 and 7) between the 11.6 - 9.1 m contour. Density of snails was estimated to be 100-300/m^2. Large concentrations of snails were not observed at other stations; often none were seen.

(7) Other macroinvertebrates were not observed; however, pieces of sphaeriid and gastropod shells were abundant, concentrated in troughs of ripple marks.

(8) Young-of-the-year alewives (20-30 mm TL) were observed at many but not all locations. Numbers were estimated to range from 1-30/m^3 for the water volume examined. Fish were most frequently seen in schools, although larger numbers of fish may simply have been more highly visible. During other underwater studies we have observed that YOY alewives tended to school together during daylight hours. Fish appeared to remain predominately within 2 m of bottom, but a few schools were noted higher in the water column.

(9) Other species of fish were not observed.

Stations examined during our 9-10 August dive studies appeared physically and limnologically homogeneous. With few exceptions (occurrence of detrital material and concentrations of snails), stations also appeared to be relatively biologically homogeneous. No unique spawning habitats were identified. However several species of fish, most notably the alewife and spottail shiner, would be expected to spawn in the vicinity of the Campbell Plant, as they do along most of the eastern Lake Michigan shoreline. From our previous experiences, we would expect yellow perch to spawn in specific areas away from the Campbell Plant. Other species, such as trout-perch, bloaters and slimy sculpins probably would use the area near Campbell for spawning purposes to some degree, but no large concentrations of fish would be expected. This area should be no more attractive than others along the shoreline. Rainbow smelt may be an exception, as the jetties, intake and discharge canal and their associated currents may be attractive to smelt during their spring spawning runs. If the future intake and discharge structures are built using riprap as many other plants along Lake Michigan have been, we would expect this rocky substrate to become attractive spawning habitat for slimy sculpins and johnny darters. In addition, some limited yellow perch spawning may also occur there.

GENERAL CONCLUSIONS

This study was an attempt to characterize fish and benthos populations in a number of ecologically distinct habitats and try to relate their distributions to present and possible future effects of a power plant. Lake Michigan with its wide expanse of water and the associated coldwater fauna that inhabit it, is one habitat type. Pigeon Lake would be a typical inland lake with typical warmwater species complexes, were it not for the influence of Lake Michigan water and the Pigeon River on its ecology. Pigeon River adds yet another facet to the study picture, because of the reservoir of riverine organisms that inhabit its stretches, and ultimately exerts its effect on the composition and abundance of species living in Pigeon Lake.

Our adult fish surveys in Lake Michigan have established that alewife, spottail shiner, rainbow smelt and yellow perch are seasonally common to abundant in the inshore region around the plant. Alewives dominate the inshore region starting in April with the first warming of inshore waters, then leave their myriad young behind after early summer. Both young and adults are an important aspect of the ecology of these waters.

There was tremendous diversity of fishes within Pigeon Lake, many species of which were not collected in Lake Michigan. This is probably due to the range of habitats available, abundant plant cover and seasonally warm temperatures. Immigration of typical Lake Michigan fish species into Pigeon Lake has important ramifications both because of influences on the biology of resident Pigeon Lake species and potential increases in entrainment.

The adult species of fishes in both lakes interact with each other in many ways. It is suspected that many Lake Michigan fish, burbot, some salmonids (lake, brown and rainbow trout, chinook and coho salmon), suckers (golden redhorse and white) and lake herring make spawning runs into Pigeon Lake; and others, such as yellow perch, spottail shiner and alewife succesfully reproduce in Pigeon Lake.

One dilemma noted was that although gizzard shad were commonly impinged on traveling screens particularly in the fall and winter (Consumers Power 1975), very few were caught in our sampling gear.

The mark and recapture study established that large numbers of northern pike and largemouth bass inhabit Pigeon Lake. These fish were utilizing the abundant food supply due in part to YOY produced by Lake Michigan fish species and the diverse habitat present in Pigeon Lake. Initial observations suggested that northern pike experience above average growth in Pigeon Lake. Considerable movement within Pigeon Lake was also noted for these large piscivores.

Fish larvae in Pigeon Lake, as expected, were quite abundant. The lake provides a sheltered environment in contrast to Lake Michigan and many species like alewives, spottail shiners and perch have been attracted there and successfully spawned. Very few larvae were collected in Lake Michigan during early June, when large numbers were collected in Pigeon Lake. Even during periods of maximum abundance of alewife larvae in Lake Michigan, we still observed higher concentrations of larvae in Pigeon Lake. The number of species of larval fish caught in Pigeon Lake were also quite high when compared to the few collected in Lake Michigan. Sled tows showed that high concentrations of spottail shiners inhabited the sandy inshore beach areas. Many other rarely captured larvae, like sculpins and trout-perch, were also taken with the sled.

Rainbow smelt larval data suggested an interesting temporal distribution pattern. Newly-hatched larvae were present at offshore Lake Michigan stations in mid-June which was considerably later than the usual occurrence of larval smelt. Peak abundance of larval smelt was probably sometime in late April-May and presence of these larvae in mid-June was puzzling. We will continue to monitor this situation closely to document whether 1977 was an unusual year for rainbow smelt larvae.

Another situation which was common for a number of larval fish species, was appearance of larvae at the north transect of stations in the area of the thermal discharge but none at the south reference transect. We believe the presence of larvae at the north transect was due to spawning by adult fish in the discharge canal. After hatching, larvae were apparently carried into Lake Michigan in the area of the thermal discharge, accounting for their appearance in north transect samples. Sampling and observation of the discharge canal in 1978 revealed that alewives were spawning there in abundance, carp YOY and small centrarchids were caught in minnow traps, spawning nests of some centrarchids were observed and adult white suckers were seen in the canal during their peak spawning period.

A prevailing theme running throughout the larval fish data analysis was the earlier spawning by fish species in Pigeon Lake compared with Lake Michigan. This phenomena resulted in dual peaks of larvae passing through plant intakes. Successive peaks of fish larvae in entrainment samples came from larval cohorts spawned in Pigeon Lake and then sometime later in Lake Michigan. This was clearly evident for the following major species: alewife, spottail shiner and yellow perch. Net avoidance biased results for all species. Factors such as macrophyte density and water turbidity, when coupled with net avoidance, resulted in different gear efficiencies among stations and between day and night. Species-specific differences were also noted. For example, the

frail, relatively slow-swimming larval alewives were collected over the entire larvae length range (0-25 mm) while more robust species like yellow perch (in Lake Michigan) were never collected at lengths over 9 mm. Of course, larger yellow perch were frequently captured in Pigeon Lake at night at stations which had turbid water and macrophytes. Daytime net avoidance by fish larvae prompts the recommendation that any calculations or generalizations about field concentrations of larvae should be based on night data for most species captured. Thus any calculations of potential entrainment impact due to the future offshore intake should use nighttime data. For some time periods and species (i.e., alewife in early June) both day and night data could be used to advantage.

A wide discrepancy existed between the large number of taxonomic groups observed in the field larval fish collections and the few groups represented in entrainment samples. Possible causes might be limited dispersion by some groups, low abundance or misidentification. Entrainment of fish larvae and fry at the Campbell plant was high during peak periods of larval abundance. Most larvae were entrained on the first sampling date (8 July) when over 4.5 million larvae in 24 hr passed through the plant. Undoubtedly, high entrainment values were also occurring in June. Values of over one million larvae per day were common through early August, but after 10 August entrainment rates dropped to less than 70,000/24 hr for the remainder of the year. Alewife, unknown cyprinids and rainbow smelt were the dominant larval groups entrained. Another 11 groups of larvae were also entrained, but in low numbers.

We have observed unusually high concentrations of larvae in the intake canal. Concentrations there were higher than those observed in Pigeon Lake or Lake Michigan. We also found that many of the larvae entrained by the Campbell Plant were derived from larval populations in Lake Michigan. Evidence for this was the consistent entrainment of alewife larvae during times when few were present in areas of Pigeon Lake outside the influence of Lake Michigan. In addition, very few larvae of resident Pigeon Lake species were ever entrained, although they were abundant at our Pigeon Lake beach and openwater stations. Contradicting this general trend was that on two occasions, yellow perch and alewife larvae, that were only present in Pigeon Lake, were entrained in large numbers. Both of these occurrences were in the spring and may have been due to water flow changes in Pigeon Lake. In the spring, Pigeon River flow was high which may have caused most intake water to come from Pigeon Lake rather than Lake Michigan, as was the case later in the year. During summer and fall few Pigeon Lake endemic species were entrained.

Peak numbers of fry entrained occurred later in the season, reflecting growth of larvae as the season progressed. The 8 August

period was the time of maximum entrainment of fry; most were alewife, but some smelt were also collected. After 8 August, some fry were collected during every sampling period through 28 November, the last time sampling was conducted in 1977.

A general pattern of entrainment was established for each larval fish species. Some species (e.g., yellow perch, unknown minnows and spottails) were susceptible to entrainment for relatively short periods followed by a nearly total absence in entrainment samples. Others, like the alewife and rainbow smelt, were entrained over nearly half a year. Reasons for these species-related differences might be ontological, behavioral changes and habitat preference changes increasing with size and mobility. Apparently the pelagic nature of alewife and smelt resulted in increased probability of encounter with intake canal currents and subsequent entrainment. Diel activity patterns resulted in high nocturnal catches of rainbow smelt.

Another common pattern observed was that many of the larvae entrained were relatively small, newly-hatched individuals, despite presence of a wide range of larger larvae in Pigeon Lake and Lake Michigan. This indicated that many species of larvae were relatively susceptible to prevailing water currents just after hatching and as a result vulnerable to entrainment.

After working with the fish larvae data sets from Pigeon Lake and Lake Michigan and trying to understand the distribution and behavior of fish larvae species as they interact with the various water bodies and current processes occurring around the Campbell Plant, we were struck with the complexity of this ecosystem. Not only were there different species complexes in the three systems (Pigeon Lake, Pigeon River, Lake Michigan), but they spawned at different times and undoubtedly there was crossover spawning--Lake Michigan fish spawning and migrating to Pigeon Lake and vice-versa. Superimposed on this artificial system was the additional vector of entrainment and impingement mortality caused by the Campbell Plant. Two factors must be considered here. On the one hand, the plant was responsible for building the jetties (good new spawning habitat), they created a cold, clear source of oxygen-rich water which flows through Pigeon Lake (prevents stratification and attracts fish), built the intake and discharge canal (also new spawning habitat) and discharged heated water to Lake Michigan which creates favorable habitat for early spawning and attracts fish. On the other hand, the plant destroys a large number of larval and adult fish, cropping the organisms that come under the influence of its intake system. It may also stress or kill fish that are attracted into the discharge canal. In the final analysis, one must weigh the fact that the plant was not only responsible for the destruction of many fishes, but was also instrumental in creating and maintaining habitat favorable for fish reproduction which would not occur were the plant not there. As a

matter of historical fact, residents on the lake have noted that the Pigeon Lake outlet, before the plant reconstructed it for use as an inlet, was little more than a transient opening to Lake Michigan. Now it is maintained through dredging as a safe harbor and access point to Lake Michigan. These same residents have remarked on the improvement in sport fishing.

Results of the benthos survey showed that high concentrations of the amphipod, Pontoporeia affinis, were observed at the 15 m depth contour in June. Other differences between the potentially affected area and reference areas north and south were documented by utilizing data on benthic community structure and composition. Patterns of benthic distribution at Campbell were similar in most respects to what has been observed elsewere in Lake Michigan, but differed in several aspects. One hypothesis suggested to account for the higher concentrations of benthic organisms at 15 m off Campbell is related to possible transport of detritus and nutrients from the discharge canal as well as the presence of an exposed layer of moraine in this area.

The final study, SCUBA observations, has shown this part of the inshore region of Lake Michigan to be a fairly typical sandy, featureless habitat common to the eastern and southeastern shore of the lake. A few objects (sticks, logs), fish, snails and some detrital material were observed. No unique spawning habitat for fish was noted.

Stations examined during our 9-10 August dive studies appeared physically and limnologically homogeneous. With few exceptions (occurrence of detrital material and concentrations of snails), stations also appeared to be relatively homogeneous biologically. No unique spawning habitats were identified. However, several species of fish, most notably the alewife and spottail shiner, would be expected to spawn in the vicinity of the Campbell plant, as they do along most of the eastern Lake Michigan shoreline. From our previous experiences, we would expect yellow perch to spawn in specific areas away from the Campbell Plant. Other species, such as trout-perch, bloaters and slimy sculpins probably would use the area near Campbell for spawning purposes to some degree, but no large concentrations of fish would be expected. This area should be no more attractive than others along the shoreline. Rainbow smelt may be an exception, as the jetties, intake and discharge canal and their associated currents may be attractive to smelt during their spring spawning runs. If the future intake and discharge structures are built using riprap as many other plants along Lake Michigan were, we would expect this rocky substrate to become attractive spawning habitat for slimy sculpins and johnny darters. In addition, some limited yellow perch spawning may also occur there.

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APPENDIX 1

APPENDIX 1. Date and time of day gill nets were used, as well as some physical and limnological parameters measured at the time of collection.

Starting date	Time: Start	Time: Finish	Station	Temperature C: Surface	Temperature C: Fish depth	Wind: Dir. from	Wind: Speed mph	Waves: Dir. from	Waves: Ht. (m)	Weather	Secchi disc (m)
6-3-77	1100	2015	A	9.0	7.5	SW	0-5	SW	0.2	Clear	1.5
6-3-77	1050	2010	B	9.0	7.0	SW	0-5	SW	Calm	Clear	3.0
6-3-77	1110	2005	C	8.5	5.5	SW	0-5	Calm		Clear	2.5
6-3-77	1110	2000	C(H)*	8.5	8.5	SW	0-5	Calm		Clear	2.5
6-3-77	1135	1935	D	8.5	5.0	SW	0-5	Calm		Clear	2.2
6-3-77	1135	1950	D(H)	8.5	8.5	SW	0-5	Calm		Clear	2.2
6-3-77	1150	1940	E	8.5	5.0	SW	0-5	Calm		Clear	2.6
6-3-77	1150	1935	E(H)	8.5	8.5	SW	0-5	Calm		Clear	2.6
6-3-77	1225	1935	L	12.0	5.5	SW	0-5	Calm		Clear	2.4
6-3-77	1225	1935	L(H)	12.0	12.0	SW	0-5	Calm		Clear	2.4
6-2-77	0630	1900	M	13.2	13.2	N	5-10	Calm		Clear	1.4
6-1-77	1905	0630	M	12.0	10.3	- Calm	-	Calm		Overcast	--
6-2-77	0700	1900	Y	18.0	17.9	N	5-10	Calm		Clear	0.6
6-1-77	1920	0630	Y	17.9	17.9	Calm		Calm		Overcast	--
7-27-77	1025	1915	A	9.9	8.9	--	0-5	Calm		Clear	1.5
7-26-77	0020	0530	A	14.8	10.5	NE	0-5	NW	0.2	Clear	--
7-27-77	1033	1930	B	10.5	8.0	--	0-5	Calm		Clear	2.6
7-26-77	0010	0540	B	13.5	8.6	NE	0-5	NW	0.2	Clear	--
7-27-77	1047	1951	C	10.4	7.9	--	0-5	Calm		Clear	2.6
7-25-77	2250	0555	C	12.5	8.2	NE	0-5	NW	0.2	Clear	--
7-27-77	1047	1945	C(H)	10.4	10.4	S-SW	0-5	Calm		Clear	2.6
7-25-77	2250	0555	C(H)	12.5	12.5	NE	0-5	NW	0.2	Clear	--
7-27-77	1040	1935	D	11.0	6.2	E	0-5	Calm		Clear	3.7
7-25-77	2330	0552	D	14.0	17.5	NE	5-10	NW	0.2	Clear	--
7-27-77	1040	1935	D(H)	11.0	11.0	E	0-5	Calm		Clear	3.8
7-25-77	2330	0552	D(H)	14.0	14.0	NE	5-10	NW	0.2	Clear	--
7-27-77	1020	1930	E	11.0	6.0	E	0-5	Calm		Clear	4.0
7-25-77	2300	0530	E	15.0	7.7	E	0-5	NW	0.2	Clear	--
7-27-77	1020	1930	E(H)	11.0	11.0	E	0-5	Calm		Clear	4.0
7-25-77	2300	0530	E(H)	15.0	15.0	NE	0-5	NW	0.2	Clear	--

APPENDIX 1. (continued)

Starting date	Time: Start	Time: Finish	Station	Temperature C: Surface	Temperature C: Fish depth	Wind: Dir. from	Wind: Speed mph	Waves: Dir. from	Waves: Ht. (m)	Weather	Secchi disc (m)
7-27-77	1000	1950	L	14.6	5.8	SW	0-5	Calm		Clear	3.0
7-25-77	2230	0630	L	16.5	8.5	NE	0-5	NW	0.2	Clear	--
7-27-77	1000	1950	L(H)	14.6	14.6	SW	0-5	Calm		Clear	3.0
7-25-77	2230	0630	L(H)	16.5	16.5	NE	0-5	NW	0.2	Clear	--
7-27-77	0615	1900	M	13.4	8.9	--	0-5	Calm		Clear	2.5
7-26-77	2245	0600	M	15.9	10.9	--	0-5	Calm		Clear	--
7-27-77	0545	1845	Y	19.3	19.2	--	0-5	Calm		Clear	--
7-26-77	2230	0530	Y	21.9	19.2	--	0-5	Calm		Clear	--
8-18-77	0858	1810	A	10.7	10.2	NE	5-10	NW	0.2	Clear	1.1
8-15-77	2202	0600	A	21.6	21.5	SW	10-15	SW	0.3	Overcast	--
8-18-77	0853	1803	B	14.0	9.4	NE	5-10	NW	0.2	Clear	2.2
8-15-77	2153	0610	B	21.5	20.5	SW	10-15	SW	0.8	Overcast	--
8-18-77	0937	1519	C	17.2	8.1	NE	0-5	NW	0.2	Clear	3.2
8-15-77	2145	0615	C	21.5	20.3	SW	10-15	SW	0.6-0.8	Overcast	--
8-18-77	0935	1515	C(H)	17.2	17.2	NE	5-10	NW	0.8	Clear	3.2
8-18-77	0943	1530	D	18.5	13.3	NE	5-10	--	0.2	Clear	3.0
8-18-77	2133	0624	D	21.5	18.5	SW	10-15	SW	0.6-1.0	Overcast	--
8-18-77	0950	1530	D(H)	18.5	18.5	NE	5-10	NW	0.2	Clear	3.0
8-18-77	0850	1750	E	17.8	6.1	NE	0-5	NW	0.2	Clear	4.0
8-15-77	2120	0630	E	22.5	19.5	SW	10-15	SW	0.8-1.0	Overcast	--
8-18-77	0855	1745	E(H)	17.8	17.8	NE	5-10	NW	0.2	Clear	4.0
8-18-77	0820	1637	L	20.0	8.7	NE	5-10	NW	0.2	Clear	2.0
8-15-77	2230	0657	L	21.5	20.0	NE	5-10	--	0.3-0.6	Overcast	--
8-18-77	0820	1637	L(H)	20.0	20.0	NE	5-10	NW	0.5	Clear	2.0
8-17-77	0755	1840	M	21.3	20.9	SW	0-5	SW	0.1	Pt. cloudy	1.5
8-15-77	1955	0535	M	22.2	21.1	SE	0-5	Calm		Pt. cloudy	--
8-17-77	0820	1909	Y	21.6	21.2	W	0-5	W	0.1	Pt. cloudy	2.5
8-15-77	2015	0600	Y	22.2	22.2	SE	0-5	Calm		Pt. cloudy	--
9-21-77	1030	1940	A	10.6	8.2	NE	0-5	NW	0.2	Overcast	1.2
9-21-77	2325	0730	A	10.2	10.0	SE	0-5	NW	0.2	Overcast	--
9-21-77	1035	1930	B	11.1	8.2	NE	0-5	NW	0.2	Overcast	1.5
9-21-77	2330	0735	B	10.2	8.1	SE	0-5	NW	0.2	Overcast	--
9-21-77	1045	1920	C	10.7	6.6	NE	0-5	NW	0.2	Overcast	2.0
9-21-77	2336	0745	C	8.9	7.3	SE	0-5	NW	0.2	Overcast	--

APPENDIX 1. (continued)

Starting date	Time		Station	Temperature C		Wind		Waves		Weather	Secchi disc (m)
	Start	Finish		Surface	Fish depth	Dir. from	Speed mph	Dir. from	Ht. (m)		
9-21-77	1115	1920	C(H)	10.7	10.7	NE	0-5	NW	0.2	Overcast	2.0
9-21-77	1925	0810	C(H)	9.0	9.0	NE	0-5	NW	0.3	Overcast	--
9-21-77	1050	1650	D	12.3	6.1	NE	0-5	NW	0.2	Overcast	2.0
9-21-77	2243	0755	D	9.7	6.7	SE	0-5	NW	0.2	Overcast	--
9-21-77	1100	1840	E	12.6	5.6	NE	0-5	NW	0.2	Overcast	2.5
9-21-77	2350	0758	E	10.0	6.5	SE	0-5	NW	0.2	Overcast	--
9-21-77	1000	1925	L	10.6	7.1	NE	0-5	NW	0.2	Overcast	1.5
9-21-77	2315	0715	L	6.1	6.0	SE	0-5	NW	0.2	Overcast	--
9-21-77	1000	1900	L(H)	10.6	10.6	NE	0-5	NW	0.2	Overcast	1.5
9-21-77	2330	0720	L(H)	6.1	6.1	SE	0-5	NW	0.2	Overcast	--
9-22-77	0735	1850	M	13.4	8.2	SE	0-5	Calm		Overcast	1.9
9-20-77	1910	0711	M	16.7	17.0	N	10-15	Calm		Overcast	--
9-21-77	0630	1900	Y	14.4	14.4	NE	10-15	Calm		Overcast	--
9-20-77	1900	0630	Y	15.0	15.0	N	5-10	Calm		Overcast	--
10-18-77	0910	1740	M	9.5	9.5	W	0-5	Calm		Overcast	1.3
10-17-77	1835	0700	M	10.1	9.7	SW	0-5	Calm		--	--
10-18-77	0925	1745	Y	9.0	9.0	SW	0-5	Calm		Overcast	
10-17-77	1850	0730	Y	8.0	8.0	SW	5-10	Calm		Clear	--
11-1-77	0830	1750	A	11.3	11.3	SE	10-15	SW	0.3-0.6	Overcast	--
11-2-77	1750	0715	A	13.5	12.9	SE	0-5	Calm		Pt. cloudy	--
11-1-77	0840	1800	B	10.8	10.8	SE	10-15	SW	0.3-0.6	Pt. cloudy	--
11-2-77	1800	0705	B	12.1	12.0	SE	0-5	Calm		Pt. cloudy	--
11-1-77	0850	1750	C	10.6	10.6	SE	10-15	SW	0.3-0.6	Overcast	--
11-2-77	1805	0655	C	12.3	11.9	SE	0-5	Calm		Pt. cloudy	--
11-1-77	0915	1745	C(H)	10.6	10.6	SE	10-15	SW	0.3-0.6	Pt. cloudy	--
11-2-77	1810	0650	C(H)	12.3	12.3	SE	0-5	Calm		Pt. cloudy	--
11-1-77	0925	1735	D	10.9	10.6	SE	10-15	SW	0.3-0.6	--	--
11-2-77	1820	0640	D	11.7	11.5	SE	5-10	Calm		Pt. cloudy	--
11-1-77	0934	1725	E	10.5	10.5	SE	10-15	SW	0.3-0.6	--	--
11-2-77	1830	0710	E	11.4	11.1	SE	0-5	Calm		Pt. cloudy	--
11-1-77	1010	1730	L	12.6	12.6	SE	15-20	SW	0.6-1.0	Overcast	3.8
11-2-77	1820	0640	L	15.3	15.3	--	0-5	Calm		Clear	--
11-1-77	1020	1720	L(H)	12.6	10.5	SE	15-20	SW	0.6-1.0	Overcast	3.8

APPENDIX 1. (continued)

Starting date	Time: Start	Time: Finish	Station	Temperature C: Surface	Temperature C: Fish depth	Wind: Dir. from	Wind: Speed mph	Waves: Dir. from	Waves: Ht. (m)	Weather	Secchi disc (m)
11-2-77	1810	0610	L(H)	15.3	15.3	--	0.5	Calm		Clear	--
11-2-77	0830	1640	M	11.4	11.1	SE	5-10	Calm		Clear	2.2
11-1-77	2205	0805	M	11.0	10.9	SE	5-10	SE	0.1	Rain	--
11-2-77	0752	1712	Y	10.7	11.0	SE	5-10	Calm		Pt. cloudy	1.2
11-1-77	2050	0745	Y	11.0	10.9	SE	5-10	SE	0.1	Overcast	--
12-16-77	1043	1640	C	.6	1.0	SE	10-15	SW	0.3-0.6	Clear	0.8
12-16-77	1043	1647	D	1.0	1.0	SE	10-15	SW	0.3-0.6	Clear	0.8
12-16-77	1010	1605	L	0.6	1.0	SE	10-15	SW	0.3	Clear	0.7
12-7-77	1010	1715	M	3.0	3.2	NW	5-10	Calm		Overcast	1.3
12-7-77	1750	0915	M	2.4	2.5	E	10-15	E	0.1	Overcast	--
12-7-77	1110	1745	Y	0.2	0.5	NW	5-10	Calm		Overcast	1.0

* The letter (H) following a station name indicates a surface gill net set at that station.

APPENDIX 2

APPENDIX 2. Date and time of day seines were used, as well as some physical and limnological parameters measured at the time of collection.

Starting date	Diel	Time	Station	Temperature		Wind		Waves		Weather
		Start		Surface	Fish depth	Dir	Speed	Dir	Height (m)	
6-3-77	D	1232	P	13.0	13.0	SW	0-5	SW	0.2	Clear
6-3-77	D	1238	P	13.0	13.0	SW	0-5	SW	0.2	Clear
6-3-77	N	0010	P	9.5	9.5	SW	0-5		Calm	Clear
6-3-77	N	0020	P	9.5	9.5	SW	0-5		Calm	Clear
6-3-77	D	1137	Q	17.0	17.0	SW	0-5	SW	0.2	Clear
6-3-77	D	1145	Q	17.0	17.0	SW	0-5	SW	0.2	Clear
6-3-77	N	2330	Q	8.0	8.0	SW	0-5		Calm	Clear
6-3-77	N	2340	Q	8.0	8.0	SW	0-5		Calm	Clear
6-3-77	D	1045	R	12.0	12.0	SW	0-5	SW	0.2	Clear
6-3-77	D	1055	R	12.0	12.0	SW	0-5	SW	0.2	Clear
6-3-77	N	2250	R	10.6	10.6	SW	0-5		Calm	Clear
6-3-77	N	2300	R	10.6	10.6	SW	0-5		Calm	Clear
6-1-77	D	1625	S	11.2	11.0	Var	0-5		Calm	Overcast
6-1-77	D	1635	S	11.2	11.0	Var	0-5		Calm	Overcast
6-1-77	N	2318	S	11.0	11.0	Var	5-10		Calm	Pt. Cloudy
6-1-77	N	2328	S	11.0	11.0	Var	5-10		Calm	Pt. Cloudy
6-1-77	D	1742	T	12.0	12.0	Var	5-10		Calm	Overcast
6-1-77	D	1750	T	12.0	12.0	Var	0-5		Calm	Overcast
6-2-77	N	0030	T	16.6	16.6	Var	5-10		Calm	Pt. Cloudy
6-2-77	N	0045	T	16.6	16.6	Var	5-10		Calm	Pt. Cloudy
6-1-77	D	1704	V	12.2	12.2	Var	0-5		Calm	Overcast
6-1-77	D	1710	V	12.2	12.2	Var	0-5		Calm	Overcast
6-1-77	N	2345	V	14.0	13.5	Var	5-10		Calm	Pt. Cloudy
6-1-77	N	2355	V	14.0	13.5	Var	5-10		Calm	Pt. Cloudy

APPENDIX 2. (continued)

Starting date	Diel	Time Start	Station	Temperature Surface	Temperature Fish depth	Wind Dir	Wind Speed	Waves Dir	Waves Height (m)	Weather
7-26-77	D	1251	P	16.0	15.5	NW	10-15	NW	0.6-1.3	Clear
7-26-77	D	1300	P	16.0	15.5	NW	5-10	NW	0.6-1.3	Clear
7-25-77	N	2335	P	16.0	16.0	NE	0-5	W	0.3	Clear
7-25-77	N	2344	P	16.0	16.0	NE	0-5	W	0.3	Clear
7-26-77	D	1513	Q	22.0	21.5	NW	10-15	NW	1.0	Pt. Cloudy
7-26-77	D	1519	Q	22.0	21.5	NW	10-15	NW	1.0	Pt. Cloudy
7-25-77	N	2248	Q	20.0	20.0	NE	5-10	W	0.3-0.6	Clear
7-25-77	N	2300	Q	20.0	20.0	NE	5-10	W	0.3-0.6	Clear
7-26-77	D	1422	R	15.7	15.7	NW	5-10	NW	1.0	Pt. Cloudy
7-26-77	D	1429	R	15.7	15.7	NW	10-15	NW	1.0	Pt. Cloudy
7-25-77	N	2200	R	17.0	17.0	NE	5-10	W	0.3	Clear
7-25-77	N	2210	R	17.0	17.0	NE	5-10	W	0.3	Clear
7-27-77	D	1458	S	13.8	12.5	S-SW	5-10	Calm		Clear
7-27-77	D	1520	S	13.8	12.5	S-SW	5-10	Calm		Clear
7-26-77	N	2200	S	15.6	15.3	N	0-5	Calm		Clear
7-26-77	N	2215	S	15.6	15.3	N	0-5	Calm		Clear
7-27-77	D	1637	T	25.3	23.9	S-SW	5-10	Calm		Clear
7-27-77	D	1700	T	25.3	23.9	S-SW	0-5	Calm		Clear
7-27-77	N	0020	T	19.0	19.0	N	0-5	Calm		Pt. Cloudy
7-27-77	N	0040	T	19.0	19.0	N	0-5	Calm		Pt. Cloudy
7-27-77	D	1550	V	16.5	15.9	S-SW	0-5	Calm		Clear
7-27-77	D	1616	V	16.5	15.9	S-SW	5-10	Calm		Clear
7-26-77	N	2310	V	19.0	19.0	N	0-5	Calm		Clear
7-26-77	N	2330	V	19.0	19.0	N	0-5	Calm		Clear

APPENDIX 2. (continued)

Starting date	Diel	Time Start	Station	Temperature Surface	Temperature Fish depth	Wind Dir	Wind Speed	Waves Dir	Waves Height (m)	Weather
8-15-77	D	1815	P	24.7	24.5	NW	10-15	NW	0.3	Clear
8-15-77	D	1825	P	24.7	24.5	NW	10-15	NW	0.3	Clear
8-16-77	N	0155	P	21.5	21.5	SSW	5-10	SW	0.3	Rain
8-16-77	N	0205	P	21.5	21.5	SSW	5-10	SW	0.3	Rain
8-15-77	D	1735	Q	25.0	28.2	Var	0-5	NW	0.2	Clear
8-15-77	D	1740	Q	25.0	22.2	Var	0-5	NW	0.2	Clear
8-16-77	N	0105	Q	20.6	20.6	SSW	0-5	S	0.2	Cloudy
8-16-77	N	0115	Q	20.6	20.6	SSW	0-5	S	0.2	Cloudy
8-15-77	D	1650	R	24.4	24.4	NE	0-5	NE	0.2	Clear
8-15-77	D	1700	R	24.4	24.4	NE	0-5	NE	0.2	Clear
8-16-77	N	0010	R	21.5	21.5	SE	0-5	S	0.2	Pt. Cloudy
8-16-77	N	0025	R	21.5	21.5	S	0-5	S	0.2	Pt. Cloudy
8-13-77	D	1614	S	22.8	22.8	S	5-10	Calm		Clear
8-13-77	D	1631	S	22.8	22.8	S	5-10	Calm		Clear
8-14-77	N	C107	S	21.8	21.8	SW	0-5	Calm		Pt. Cloudy
8-14-77	N	0125	S	21.8	21.8	SW	0-5	Calm		Pt. Cloudy
8-13-77	D	1310	T	23.4	23.4	E	10-15	Calm		Clear
8-13-77	D	1343	T	23.4	23.4	E	10-15	Calm		Clear
8-13-77	N	2220	T	22.6	22.6	SW	5-10	Calm		Rain
8-13-77	N	2315	T	22.6	22.6	SW	5-10	Calm		Rain
8-13-77	D	1510	V	26.5	26.5	S	5-10	Calm		Clear
8-13-77	D	1530	V	26.5	26.5	S	5-10	Calm		Clear
8-13-77	N	0012	V	23.0	23.0	SW	0-5	Calm		Pt. Cloudy
8-13-77	N	0040	V	23.0	23.0	SW	0-5	Calm		Pt. Cloudy

APPENDIX 2. (continued)

Starting date	Diel	Time	Station	Temperature		Wind		Waves		Weather
		Start		Surface	Fish depth	Dir	Speed	Dir	Height (m)	
9-21-77	D	1500	P	11.1	11.1	NE	5-10	NW	0.3	Pt. Cloudy
9-21-77	D	1510	P	11.1	11.1	NE	5-10	NW	0.3	Pt. Cloudy
9-22-77	N	2130	P	12.5	12.5	SE	0-5	Calm		Overcast
9-22-77	N	2130	P	12.5	12.5	SE	0-5	Calm		Overcast
9-21-77	D	1550	Q	16.7	15.6	NE	5-10	NW	0.3	Overcast
9-21-77	D	1555	Q	16.7	15.6	NE	5-10	NW	0.3	Overcast
9-22-77	N	2205	Q	10.0	10.0	SE	0-5	Calm		Overcast
9-22-77	N	2215	Q	10.0	10.0	SE	0-5	Calm		Overcast
9-21-77	D	1645	R	12.2	12.2	NE	5-10	NW	0.3	Overcast
9-21-77	D	1635	R	12.2	12.2	NE	5-10	NW	0.3	Overcast
9-22-77	N	2245	R	12.0	12.0	SE	0-5	Calm		Overcast
9-22-77	N	2255	R	12.0	12.0	SE	0-5	Calm		Overcast
9-19-77	D	1625	S	17.0	17.0	NW	20-25	NW	0.3	Overcast
9-19-77	D	1635	S	17.0	17.0	NW	20-25	NW	0.3	Overcast
9-20-77	N	0050	S	17.0	17.0	N	10-15	Calm		Overcast
9-20-77	N	0100	S	17.0	17.0	N	10-15	Calm		Overcast
9-19-77	D	1750	T	17.8	17.8	NW	15-20	Calm		Overcast
9-19-77	D	1800	T	17.8	17.8	NW	15-20	Calm		Overcast
9-19-77	N	2300	T	16.7	16.7	N	15-20	Calm		Overcast
9-19-77	N	2315	T	16.7	16.7	N	15-20	Calm		Overcast
9-19-77	D	1705	V	16.7	16.7	NW	15-20	Calm		Overcast
9-19-77	D	1720	V	16.7	16.7	NW	15-20	Calm		Overcast
9-20-77	N	0005	V	16.7	16.7	N	10-15	Calm		Overcast
9-20-77	N	0015	V	16.7	16.7	N	10-15	Calm		Overcast

APPENDIX 2. (continued)

Starting date	Diel	Time Start	Station	Temperature Surface	Temperature Fish depth	Wind Dir	Wind Speed	Waves Dir	Waves Height (m)	Weather
10-20-77	D	1402	P	11.2	11.2	SW	10-15	SW	0.8-0.9	Clear
10-20-77	D	1407	P	11.2	11.2	SW	10-15	SW	0.8-0.9	Clear
10-19-77	N	2230	P	10.5	10.5	NE	5-10	N	0.6	Clear
10-19-77	N	2240	P	10.5	10.5	NE	5-10	N	0.6	Clear
10-20-77	D	1315	Q	11.2	11.2	SW	10-15	SW	0.6-0.8	Clear
10-20-77	D	1323	Q	11.2	11.2	SW	10-15	SW	0.6-0.8	Clear
10-19-77	N	2145	Q	12.9	12.9	N	10-15	N	0.6-0.8	Clear
10-19-77	N	2150	Q	12.9	12.9	N	10-15	N	0.6-0.8	Clear
10-20-77	D	1210	R	14.0	14.0	SW	10-15	SW	0.6	Clear
10-20-77	D	1215	R	14.0	14.0	SW	10-15	SW	0.6	Clear
10-19-77	N	2105	R	10.0	10.0	N	10-15	N	0.6-0.8	Clear
10-19-77	N	2110	R	10.0	10.0	N	10-15	N	0.6-0.8	Clear
10-17-77	D	1810	S	11.2	11.2	SW	10-15	Calm		Rain
10-17-77	D	1820	S	11.2	11.2	SW	10-15	Calm		Rain
10-17-77	N	1920	S	11.2	11.2	SW	5-10	Calm		Rain
10-17-77	N	1930	S	11.2	11.2	SW	5-10	Calm		Rain
10-17-77	D	1710	T	15.5	15.5	SW	5-10	Calm		Rain
10-17-77	D	1715	T	15.5	15.5	SW	5-10	Calm		Overcast
10-17-77	N	2000	T	8.0	8.0	SW	5-10	Calm		Rain
10-17-77	N	2010	T	8.0	8.0	SW	5-10	Calm		Rain
10-17-77	D	1745	V	18.1	18.1	SW	5-10	Calm		Overcast
10-17-77	D	1755	V	18.1	18.1	SW	5-10	Calm		Overcast
10-17-77	N	2105	V	8.0	8,0	SW	5-10	Calm		Rain
10-17-77	N	2110	V	8.0	8.0	SW	5-10	Calm		Rain

APPENDIX 2. (continued)

Starting date	Diel	Time	Station	Temperature		Wind		Waves		Weather
		Start		Surface	Fish depth	Dir	Speed	Dir	Height (m)	
10-31-77	D	1700	P	11.3	11.1	SE	15-20	S	0.6	Overcast
10-31-77	D	1710	P	11.3	11.1	SE	15-20	S	0.6	Overcast
11-2-77	N	2335	P	11.8	12.0	SE	0-5	SW	0	Pt. Cloudy
11-2-77	N	2346	P	11.8	12.0	SE	0-5	SW	0	Pt. Cloudy
10-31-77	D	1605	Q	10.7	10.9	SE	15-20	S	0.6	Overcast
10-31-77	D	1610	Q	10.7	10.9	SE	15-20	S	0.6	Overcast
11-2-77	N	2355	Q	12.2	12.2	SE	5-10	SW	0	Pt. Cloudy
11-2-77	N	2401	Q	12.2	12.2	SE	5-10	SW	0	Pt. Cloudy
10-31-77	D	1525	R	15.5	15.5	SE	15-20	S	0.6	Overcast
10-31-77	D	1535	R	15.5	15.5	SE	15-20	S	0.6	Overcast
11-2-77	N	2208	R	11.8	12.0	SE	0-5	SW	0	Pt. Cloudy
11-2-77	N	2220	R	11.8	12.0	SE	0-5	SW	0	Pt. Cloudy
11-1-77	D	1355	S	11.5	11.5	SE	5-10	Calm		Rain
11-1-77	D	1405	S	11.5	11.5	SE	5-10	Calm		Rain
11-1-77	N	2055	S	11.0	11.0	SE	10-15	Calm		Rain
11-1-77	N	2110	S	11.0	11.0	SE	10-15	Calm		Rain
11-1-77	D	1510	T	10.9	10.9	SW	5-10	Calm		Rain
11-1-77	D	1525	T	10.9	10.9	SW	5-10	Calm		Overcast
11-1-77	N	2220	T	10.9	10.9	SE	10-15	Calm		Rain
11-1-77	N	2235	T	10.9	10.9	SE	10-15	Calm		Rain
11-1-77	D	1425	V	12.6	12.6	N-NW	5-10	Calm		Rain
11-1-77	D	1435	V	12.6	12.6	N-NW	5-10	Calm		Rain
11-1-77	N	2135	V	12.6	12.6	SE	10-15	Calm		Rain
11-1-77	N	2150	V	12.6	12.6	SE	10-15	Calm		Rain

APPENDIX 3

APPENDIX 3. Date and time of day trawling gear was used, as well as some physical and limnological parameters measured at the time of collection.

Starting date	Time		Station	Temperature C		Wind		Waves		Weather	Secchi disc (m)
	Start	Finish		Surface	Fish depth	Dir from	Speed mph	Dir from	Ht. (m)		
6-2-77	1223	1233	C	11.7	11.7	NW	15-20	NW	1-1.3	Clear	2.0
6-2-77	1241	1251	C	11.7	11.7	NW	15-20	N	1-1.3	Clear	2.0
6-2-77	2243	2257	C	8.6	6.5	Var	0-5	NW	0.3	Clear	--
6-2-77	2304	2314	C	8.6	6.5	Var	0-5	Calm	0.3	Clear	--
6-2-77	1351	1401	D	10.0	7.4	--	--	NW	0.6	Clear	2.0
6-2-77	1411	1421	D	10.0	7.4	--	--	NW	0.6	Clear	2.0
6-2-77	2210	2220	D	8.2	6.4	Var	0-5	NW	0.3	Clear	--
6-2-77	2230	2240	D	8.2	6.4	Var	0-5	NW	0.3	Clear	--
6-2-77	1434	1444	E	8.4	6.2	NW	10-15	NW	1.0	Clear	2.0
6-2-77	1454	1504	E	8.4	6.2	NW	10-15	NW	1.0	Clear	2.0
6-2-77	2129	2139	E	6.9	6.0	N	5-10	NW	0.3-0.6	Clear	--
6-2-77	2152	2202	E	6.9	6.0	N	5-10	NW	0.3-0.6	Clear	--
6-2-77	1524	1534	F	8.4	6.1	NW	5-10	NW	1.0	Clear	2.3
6-2-77	1548	1558	F	8.4	6.1	NW	5-10	NW	1.0	Clear	2.3
6-2-77	2044	2054	F	7.4	5.5	NE	10-15	NW	0.6	Clear	--
6-2-77	2105	2115	F	7.4	5.5	N	5-10	NW	0.6	Clear	--
6-2-77	1618	1628	G	7.4	4.5	NW	10-15	NW	1.0	Clear	2.0
6-2-77	1645	1655	G	7.4	4.5	NW	10-15	NW	1.0	Clear	2.0
6-2-77	1716	1726	H	8.1	4.4	NW	15-20	NW	1.2	Clear	2.0
6-2-77	1749	1759	H	8.1	4.4	NW	15-20	NW	1.3	Clear	2.0
6-2-77	1130	1140	L	9.8	7.8	NW	15-20	NW	0.6-1.0	Clear	2.0
6-2-77	1151	1201	L	9.8	7.8	NW	15-20	NW	0.6-1.0	Clear	2.0
6-2-77	2329	2339	L	8.2	5.3	Var	0-5	NW	0.3	Clear	--
6-2-77	2345	2355	L	8.2	5.3	Var	0-5	NW	0.3	Clear	--
7-26-77	1222	1232	C	10.6	8.1	N	10-15	NW	0.5-0.6	Clear	2.0
7-26-77	1240	1250	C	10.6	8.1	NW	10-15	NW	0.5-0.8	Clear	2.0
7-26-77	2250	2300	D	9.8	7.0	N	5-10	NW	0.2	Clear	--
7-26-77	2307	2317	C	9.8	7.0	N	5-10	NW	0.2	Clear	--
7-26-77	1258	1308	D	12.2	7.7	NW	15-20	NW	0.6	Clear	2.0
7-26-77	1320	1330	D	12.2	7.7	NW	15-20	NW	0.6	Clear	2.0
7-26-77	2212	2222	D	8.0	6.8	N	5-10	NW	0.2	Clear	--
7-26-77	2230	2240	D	8.0	6.8	N	5-10	NW	0.2	Clear	--
7-26-77	1339	1349	E	11.0	7.2	NW	15-20	NW	0.8	Clear	2.2
7-26-77	1405	1415	E	11.0	7.2	NW	15-20	NW	0.8	Clear	2.2

APPENDIX 3. (continued)

Starting date	Time Start	Time Finish	Station	Temperature C Surface	Temperature C Fish depth	Wind Dir from	Wind Speed mph	Waves Dir from	Waves Ht. (m)	Weather	Secchi disc (m)
7-26-77	2130	2140	E	10.1	6.3	N	5-10	NW	0.2	Clear	--
7-26-77	2155	2205	E	10.1	6.3	N	5-10	NW	0.2	Clear	--
7-26-77	1430	1440	F	16.5	7.5	NW	10-15	NW	0.8-1.0	Pt. cloudy	3.9
7-26-77	1452	1502	F	16.5	7.5	NW	10-15	NW	0.8-1.0	Pt. cloudy	3.9
7-26-77	2045	2055	F	10.5	6.0	NW	5-10	NW	0.2	Clear	--
7-26-77	2107	2117	F	10.5	6.0	NW	5-10	NW	0.2	Clear	--
7-26-77	1530	1540	G	14.9	6.1	NW	15-20	NW	1.2	Pt. cloudy	3.7
7-26-77	1549	1559	G	14.9	6.1	NW	15-20	NW	1.2	Pt. cloudy	3.7
7-26-77	1618	1628	H	14.0	6.0	NW	15-20	NW	1.0-1.3	Pt. cloudy	3.7
7-26-77	1640	1650	H	14.0	6.0	NW	15-20	NW	1.0-1.3	Pt. cloudy	3.7
7-26-77	1039	1049	L	13.0	7.5	NW	5-10	NW	0.6	Clear	2.0
7-26-77	1100	1110	L	13.0	7.5	NW	5-10	NW	0.6	Clear	2.0
7-26-77	2336	2346	L	8.0	7.0	NE	5-10	NW	0	Clear	--
7-26-77	2355	2405	L	8.0	7.0	NE	5-10	NW	-	Clear	--
8-15-77	1230	1240	B	21.2	22.0	NW	5-10	Calm		Clear	3.5
8-15-77	1245	1255	B	21.2	22.0	NW	0-5	Calm		Clear	3.5
8-15-77	1305	1315	C	22.0	21.0	W-NW	0-5	NW	0.2	Clear	3.7
8-15-77	1321	1331	C	22.0	21.0	W-NW	0-5	NW	0.2	Clear	3.7
8-15-77	2222	2232	C	20.3	17.0	E	5-10	Calm		Overcast	--
8-15-77	2241	2251	C	20.3	17.0	E	5-10	Calm		Overcast	--
8-15-77	1340	1350	D	21.5	19.5	W-NW	0-5	Calm		Clear	4.2
8-15-77	1358	1408	D	21.5	19.5	W-NW	0-5	Calm		Clear	4.2
8-15-77	2141	2151	D	20.6	16.1	E	5-10	NW	0.3	Overcast	--
8-15-77	2202	2212	D	20.6	16.1	E	5-10	NW	0.3	Overcast	--
8-15-77	1419	1429	E	21.2	18.0	W	0-5	Calm		Clear	4.0
8-15-77	1444	1454	E	21.2	18.0	W	0-5	Calm		Clear	4.0
8-15-77	2100	2110	E	21.0	15.0	E	5-10	NW	0.3	Pt. cloudy	--
8-15-77	2120	2130	E	21.0	15.0	E	5-10	NW	0.3	Pt. cloudy	--
8-15-77	1510	1520	F	22.0	18.0	NW	0-5	Calm		Clear	4.5
8-15-77	1531	1541	F	22.0	18.0	NW	0-5	Calm		Clear	4.5
8-15-77	2009	2019	F	21.0	9.0	N	10-15	NW	0.3	Pt. cloudy	--
8-15-77	2031	2041	F	21.0	9.0	N	10-15	NW	0.3	Pt. cloudy	--
8-15-77	1555	1605	G	21.5	10.0	NW	5-10	NW	0.2	Clear	5.5

APPENDIX 3. (continued)

	Time			Temperature C		Wind		Waves			Secchi
Starting date	Start	Finish	Station	Surface	Fish depth	Dir from	Speed mph	Dir from	Ht. (m)	Weather	disc (m)
8-15-77	1619	1629	G	21.5	10.0	NW	5-10	NW	0.2	Clear	5.5
8-15-77	1644	1654	H	21.0	9.5	NW	5-10	NW	0.2	Clear	5.5
8-15-77	1707	1717	H	21.0	9.5	NW	5-10	NW	0.2	Clear	5.5
8-15-77	1107	1117	L	22.5	21.0	E	0-5	Calm		Clear	3.0
8-15-77	1126	1136	L	22.5	21.0	E	0-5	Calm		Clear	3.0
8-15-77	2312	2322	L	20.0	18.0	E	5-10	Calm		Overcast	--
8-15-77	2331	2341	L	20.0	18.0	E	5-10	Calm		Overcast	--
9-21-77	1218	1228	B	12.2	9.3	NW	0-5	Calm	0.2	Overcast	1.7
9-21-77	1235	1245	B	12.2	9.3	NW	0-5	Calm	0.2	Overcast	1.7
9-21-77	1250	1300	C	12.8	8.7	NS	5-10	Calm	0.2	Overcast	1.9
9-21-77	1307	1317	C	12.8	8.7	NW	5-10	Calm	0.2	Overcast	1.9
9-21-77	2109	2119	C	9.0	6.6	NE	0-5	NW	0.3	Overcast	--
9-21-77	2126	2136	C	9.0	6.6	NE	0-5	NW	0.3	Overcast	--
9-21-77	1328	1338	E	13.5	7.6	N	5-10	Calm	0.2	Pt. cloudy	2.0
9-21-77	1347	1357	D	13.5	7.6	N	5-10	Calm	0.2	Pt. cloudy	2.0
9-21-77	2032	2042	D	9.5	6.5	NE	5-10	NW	0.3	Overcast	--
9-21-77	2052	2102	D	9.5	6.5	NE	5-10	NW	0.3	Overcast	--
9-21-77	1407	1417	E	11.1	7.0	NW	5-10	NW	0.2	Pt. cloudy	2.5
9-21-77	1426	1436	E	11.1	7.0	NW	5-10	NW	0.2	Pt. cloudy	2.5
9-21-77	1950	2000	E	9.5	6.4	NE	5-10	NW	0.3	Overcast	--
9-21-77	2013	2023	E	9.5	6.4	NE	5-10	NW	0.3	Overcast	--
9-21-77	1447	1457	F	12.7	6.3	N	5-10	NW	0.2	Pt. cloudy	2.1
9-21-77	1509	1519	F	12.7	6.2	N	5-10	NW	0.2	Pt. cloudy	2.1
9-21-77	1904	1914	F	11.8	6.0	NE	0-5	NW	0.3	Overcast	--
9-21-77	1925	1935	F	11.8	6.0	NE	0-5	NW	0.3	Overcast	--
9-21-77	1532	1542	G	12.0	6.0	N	10-15	NW	0.3	Pt. cloudy	2.1
9-21-77	1554	1604	G	12.0	6.0	N	10-15	NW	0.3	Pt. cloudy	2.1
9-21-77	1620	1630	H	13.0	5.1	N	10-15	NW	0.6	Overcast	2.9
9-21-77	1645	1655	H	13.0	5.1	N	10-15	NW	0.6	Overcast	2.9
9-21-77	1105	1115	L	14.0	8.4	NW	0-5	calm	0.2	Overcast	1.8
9-21-77	1120	1130	L	14.0	8.4	NW	0-5	Calm	0.2	Overcast	1.8
9-21-77	2156	2206	L	11.0	7.3	SE	0-5	Calm		Overcast	--
9-21-77	2214	2224	L	11.0	7.3	SE	0-5	Calm		Overcast	--
10-19-77	1243	1253	C	11.9	11.9	NW	15-20	NW	1.3-2.0	Pt. cloudy	2.0

APPENDIX 3. (continued)

Starting date	Time: Start	Time: Finish	Station	Temperature C: Surface	Temperature C: Fish depth	Wind: Dir from	Wind: Speed mph	Waves: Dir from	Waves: Ht. (m)	Weather	Secchi disc (m)
10-19-77	1301	1311	C	11.9	11.9	NW	15-20	NW	1.3-2.0	Pt. cloudy	2.0
10-19-77	2128	2138	C	11.2	11.0	N	0-5	N	0.6	Clear	--
10-19-77	2145	2155	C	11.2	11.0	N	0-5	N	0.6	Clear	--
10-19-77	1324	1334	D	12.1	12.1	NW	15-20	NW	1.3-2.0	Pt. cloudy	2.0
10-19-77	1344	1354	D	12.1	12.1	NW	15-20	NW	1.3-2.0	Pt. cloudy	2.0
10-19-77	2050	2100	D	11.9	11.5	N-NW	0-5	N-NW	0.6-1.0	Clear	--
10-19-77	2110	2120	D	11.9	11.5	N-NW	0-5	N-NW	0.6-1.0	Clear	--
10-19-77	1450	1500	E	12.1	12.1	NW	10-15	N-NW	1.0	Pt. cloudy	2.2
10-19-77	1509	1519	E	12.1	12.1	NW	10-15	N-NW	1.0	Pt. cloudy	2.2
10-19-77	2010	2020	E	11.9	11.5	N-NW	5-10	N-NW	1.0	Clear	--
10-19-77	2030	2040	E	11.9	11.5	N-NW	5-10	N-NW	1.0	Clear	--
10-19-77	1531	1541	F	12.0	12.0	NW	10-15	NW	1.0-2.0	Pt. cloudy	2.6
10-19-77	1611	1621	F	12.0	12.0	NW	10-15	NW	1.0-2.0	Pt. cloudy	2.6
10-19-77	1927	1937	F	11.9	11.5	NW	5-10	NW	1.0	Clear	--
10-19-77	1948	1958	F	11.9	11.5	NW	5-10	NW	1.0	Clear	--
10-19-77	1637	1647	G	11.5	11.5	NW	15-20	NW	1.0-2.3	Clear	2.6
10-19-77	1658	1708	G	11.5	11.5	NW	15-20	NW	1.0-2.3	Clear	2.6
10-19-77	1728	1738	H	11.5	11.0	NW	15-20	NW	1.0-2.0	Clear	2.8
10-19-77	1751	1801	H	11.5	11.0	NW	15-20	NW	1.0-2.0	Clear	2.8
10-19-77	1159	1209	L	11.0	11.0	W	15-20	NW	1.0	Pt. cloudy	1.5
10-19-77	1117	1127	L	11.0	11.0	W	15-20	NW	1.0	Pt. cloudy	1.5
10-19-77	2212	2222	L	11.0	11.0	N	0-5	N	0.3	Clear	--
10-19-77	2230	2240	L	11.0	11.0	N	0-5	N	0.3	Clear	--
11-1-77	1118	1128	B	11.0	10.8	SE	10-15	S	0.6	Overcast	3.1
11-1-77	1133	1143	B	11.0	10.8	SE	10-15	S	0.6	Overcast	3.1
11-1-77	1150	1200	C	10.8	10.8	SE	5-10	S	0.6	Overcast	3.5
11-1-77	1206	1216	C	10.8	10.6	SE	5-10	S	0.6	Overcast	3.5
11-1-77	1942	1952	C	11.7	11.8	S	15-20	SW	1.0	Rain	--
11-1-77	1957	2007	C	11.7	11.8	S	15-20	SW	1.0	Rain	--
11-1-77	1250	1300	D	11.1	10.9	SW	10-15	S	0.6	Rain	5.6
11-1-77	1307	1317	D	11.1	10.9	SW	10-15	S	0.6	Rain	5.6
11-1-77	1908	1918	D	11.8	11.7	S	15-20	SW	1.0-1.3	Rain	--
11-1-77	1925	1935	D	11.8	11.7	S	15-20	SW	1.0-1.3	Rain	--

APPENDIX 3. (continued)

Starting date	Time: Start	Time: Finish	Station	Temperature C: Surface	Temperature C: Fish depth	Wind: Dir from	Wind: Speed mph	Waves: Dir from	Waves: Ht. (m)	Weather	Secchi disc (m)
11-1-77	1330	1340	E	10.9	10.7	SE	5-10	S	0.6	Haze	5.8
11-1-77	1347	1357	E	10.9	10.7	SE	5-10	S	0.6	Haze	5.8
11-1-77	1831	1841	E	11.6	12.0	S	15-20	SW	1.0-1.3	Rain	--
11-1-77	1851	1901	E	11.6	12.0	S	15-20	SW	1.0-1.3	Rain	--
11-1-77	1408	1418	F	11.1	10.5	SW	10-15	S	0.6	Rain	5.0
11-1-77	1427	1437	F	11.1	10.5	SW	10-15	S	0.6	Rain	5.0
11-1-77	1745	1755	F	12.0	11.8	S	15-20	SW	1.0-1.3	Rain	--
11-1-77	1805	1815	F	12.0	11.8	S	15-20	SW	1.0-1.3	Rain	--
11-1-77	1449	1459	G	11.2	10.5	SW	10-15	SW	0.6-1.0	Rain	5.5
11-1-77	1509	1519	G	11.2	10.5	SW	10-15	SW	0.6-1.0	Rain	5.5
11-1-77	1528	1538	H	11.8	10.6	S	10-15	SW	1.0	Rain	5.5
11-1-77	1554	1604	H	11.8	10.6	S	10-15	SW	1.0	Rain	5.5
11-1-77	1030	1040	L	11.0	11.0	SE	10-15	S	0.6	Haze	4.7
11-1-77	1045	1055	L	11.0	11.0	SE	10-15	S	0.6	Haze	4.7
11-1-77	2024	2034	L	11.7	11.7	S	10-15	SW	1.0-1.3	Rain	--
11-1-77	2041	2051	L	11.7	11.7	S	10-15	SW	1.0-1.3	Rain	--
12-16-77	1355	1405	B	0.3	0.3	SE	10-15	SW	0.3	Clear	0.7
12-16-77	1413	1423	B	0.3	0.3	SE	10-15	SW	0.3	Clear	0.7
12-16-77	2024	2034	B	1.0	1.0	SE	10-15	SW	Calm	Clear	--
12-16-77	2040	2050	B	1.0	1.0	SE	10-15	Calm		Clear	--
12-16-77	1307	1317	C	0.6	1.0	SE	10-15	SW	0.3-0.6	Pt. cloudy	0.8
12-16-77	1337	1347	C	0.6	1.0	SE	10-15	SW	0.3	Clear	0.8
12-16-77	1932	1942	C	0.4	0.2	SE	10-15	SW	0.2	Clear	--
12-16-77	2005	2015	C	0.4	0.2	SE	10-15	SW	0.2	Clear	--
12-16-77	1430	1440	D	1.0	1.0	SE	10-15	SW	0.2	Clear	0.8
12-16-77	1450	1500	D	1.0	1.0	SE	10-15	SW	0.2	Clear	0.8
12-16-77	1852	1902	D	1.0	0.3	SE	10-15	SW	0.2	Clear	--
12-16-77	1911	1921	D	1.0	0.3	SE	10-15	SW	0.2	Clear	--
12-16-77	1110	1120	E	1.5	1.5	SE	10-15	SW	0.2-0.6	Clear	1.1
12-16-77	1131	1141	E	1.5	1.5	SE	10-15	SW	0.3-0.6	Clear	1.1
12-16-77	1050	1100	F	1.0	0.0	SE	1--15	SW	0.3-0.6	Clear	1.3
12-16-77	1523	1533	L	0.6	1.0	SE	15-20	SW	0.3	Clear	0.7
12-16-77	1540	1550	L	0.6	1.0	SE	15-20	SW	0.3	Clear	0.7
12-16-77	2108	2118	L	1.0	1.0	SE	10-15	SW	0.2	Clear	--
12-16-77	2125	2135	L	1.0	1.0	SE	10-15	SW	0.2	Clear	--

APPENDIX 4

APPENDIX 4. Monthly length-frequency distributions of species caught during 1977 in the Campbell Plant study area (Ottawa County, Michigan). Catches from all gear are pooled. Absence of data for either Pigeon Lake or Lake Michigan indicates no fish caught.

ALEWIFE - Lake Michigan

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
10	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
20	0	0	106	1	0	0	0	0	0	1	0	0	0	0	106	2
30	0	0	430	1089	3659	507	1499	39	1120	89	169	58	0	0	6877	1782
40	0	0	1111	2239	2997	4821	4152	107	2309	328	833	286	0	0	11402	7781
50	0	0	55	5	104	826	2260	647	762	436	958	215	0	0	4139	2129
60	0	0	0	0	43	232	4276	305	1611	891	2249	29	0	0	8179	1457
70	0	0	0	1	1	83	1549	101	693	634	1443	4	0	0	3686	823
80	4	0	3	1	0	1	191	48	94	212	121	0	0	0	413	262
90	6	32	16	1	0	2	34	35	22	183	41	0	0	0	119	253
100	3	63	14	1	0	3	23	39	0	27	2	0	0	0	42	133
110	3	10	4	3	2	0	4	3	0	0	0	0	0	0	13	16
120	4	5	0	1	2	0	4	1	0	0	0	0	0	0	10	7
130	6	5	1	1	3	1	7	1	0	0	0	0	0	0	17	8
140	17	9	8	0	1	1	12	12	0	0	0	0	0	0	38	22
150	61	53	81	27	18	18	73	30	0	0	0	0	0	0	233	128
160	164	94	182	71	100	41	280	60	0	0	0	0	0	0	726	266
170	298	200	145	77	99	48	296	52	0	0	0	0	0	0	838	377
180	288	298	84	45	23	18	123	7	0	1	0	1	0	0	518	370
190	125	282	21	10	13	7	33	3	0	0	0	0	0	0	192	302
200	38	113	8	1	5	0	3	4	0	0	0	0	0	0	54	118
210	2	5	5	1	1	0	0	0	0	0	0	0	0	0	8	6
220	8	2	0	0	0	0	0	1	0	0	0	0	0	0	8	3
TOTALS	1027	1171	2274	3576	7071	6609	14819	1495	6611	2802	5816	593	0	0	37618	16246

ALEWIFE - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
20	0	0	0	0	1	19	0	0	0	0	0	0	0	0	1	19
30	0	0	3312	0	0	155	77	27	0	0	0	0	0	0	3389	182
40	1	0	3300	0	0	0	4	19	1	0	0	0	0	0	3306	19
50	0	0	145	0	0	0	0	0	0	0	0	0	0	0	145	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
130	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
150	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
160	1	0	0	0	0	1	0	2	0	0	0	0	0	0	1	3
170	4	0	0	1	0	3	0	3	0	0	0	0	0	0	4	7
180	3	2	0	0	0	2	0	1	0	1	0	0	0	0	3	6
190	2	1	0	0	0	1	0	0	0	2	0	0	0	0	2	4
TOTALS	12	3	6757	1	1	182	81	52	1	3	0	0	0	1	6852	242

APPENDIX 4. (continued)

BANDED KILLIFISH - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
40	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0
TOTALS	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0

BIGMOUTH SHINER - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
60	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1

BLACK BULLHEAD - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
50	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
60	0	0	0	0	0	0	1	0	0	0	1	0	0	0	2	0
70	0	0	0	0	0	0	3	0	0	0	1	1	0	0	4	1
80	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
90	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	2
290	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2
310	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
320	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	3
TOTALS	0	1	0	0	0	3	4	5	0	0	2	2	0	0	6	11

APPENDIX 4. (continued)

BLACK CRAPPIE - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
30	0	0	3	0	1	0	0	0	0	0	0	0	0	0	4	0
40	0	0	29	2	0	0	0	1	1	0	0	0	0	0	30	3
50	0	0	38	8	9	2	0	0	0	0	0	0	0	0	47	10
60	0	0	1	1	6	10	1	4	0	0	0	1	0	0	8	16
70	1	0	0	0	0	5	1	16	1	1	0	3	0	0	3	25
80	0	0	0	0	0	0	0	1	2	0	0	1	0	0	2	2
90	0	1	0	0	0	0	0	2	1	0	0	0	0	0	1	3
110	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
140	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
150	0	0	0	0	0	0	0	2	0	0	0	0	1	0	1	2
160	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	1
170	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
180	0	0	0	0	1	0	0	1	0	1	0	0	0	0	1	2
190	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2
200	0	0	0	0	0	1	0	2	0	0	0	0	1	1	1	4
210	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	3
220	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0	4
230	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
250	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
270	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
TOTALS	1	2	71	14	18	19	2	32	5	4	0	6	5	4	102	81

BLACKNOSE SHINER - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
40	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TOTALS	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1

BLUEGILL - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
30	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3	0
50	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TOTALS	0	0	0	0	0	0	0	0	3	1	0	0	0	0	3	1

BLUEGILL - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	0	0	6	4	0	0	2	0	0	0	0	0	8	4
30	0	0	2	3	17	5	15	29	7	8	6	1	0	0	47	46
40	0	0	2	1	0	5	11	2	6	7	9	7	0	0	28	22
50	1	0	0	0	0	2	1	0	1	1	3	4	0	0	6	7
60	2	0	1	0	1	0	0	0	0	0	0	1	0	0	4	1
70	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
80	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
100	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
130	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
180	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTALS	4	0	5	4	24	17	27	31	17	16	19	14	0	0	96	82

BLUNTNOSE MINNOW - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
10	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
20	0	0	0	1	50	6	0	0	0	0	0	0	0	0	50	7
30	0	0	115	4	276	13	17	1	1	0	0	30	0	0	409	48
40	9	36	287	11	215	51	57	9	1	2	1	2	0	0	570	111
50	3	78	50	12	31	1	15	10	0	1	0	1	0	0	99	103
60	0	28	72	12	6	0	0	1	0	0	0	2	0	0	78	43
70	0	19	1	15	3	0	0	0	0	0	0	0	0	0	4	34
80	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	3
TOTALS	12	162	525	57	582	71	89	21	2	3	1	35	0	0	1211	349

APPENDIX 4.(continued)

BOWFIN - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
360	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
370	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
420	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
440	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
450	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	1
480	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	2
490	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
500	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
520	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	1
530	0	0	0	0	0	1	1	0	0	0	0	0	1	0	2	1
540	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	2
560	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
570	0	0	0	0	0	0	0	1	0	0	1	1	1	0	2	2
580	0	0	0	0	0	0	0	1	0	1	0	0	1	1	1	3
590	0	1	0	0	0	0	0	0	1	0	0	0	0	1	1	2
600	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	3
610	0	0	0	0	1	1	0	0	0	1	0	0	1	0	2	2
620	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
630	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
640	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	3
650	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
660	0	0	0	0	0	1	0	2	0	1	0	0	2	0	2	4
670	0	0	0	0	0	0	1	0	1	0	0	1	0	1	2	2
680	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
690	0	1	0	0	0	0	1	1	0	0	1	0	0	0	2	2
700	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1
710	0	0	0	1	0	1	0	0	0	0	0	0	0	2	0	4
720	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
750	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
760	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
TOTALS	0	4	0	1	3	6	3	10	3	14	4	5	10	7	23	47

APPENDIX 4. (continued)

BROOK SILVERSIDES - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
40	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TOTALS	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1

BROOK SILVERSIDES - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2	0
30	0	0	4	6	3	1	0	0	0	0	0	0	0	0	7	7
40	0	0	0	7	11	3	0	0	1	0	0	1	0	0	12	11
50	0	0	0	6	4	2	1	12	1	0	1	0	0	0	7	20
60	1	1	0	0	0	4	1	23	1	2	0	0	0	0	3	30
70	0	2	0	0	0	0	4	17	0	4	0	0	0	0	4	23
80	0	4	0	0	0	1	0	16	0	1	0	3	0	0	0	25
90	0	1	0	0	0	1	0	3	0	0	0	0	0	0	0	5
100	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
TOTALS	1	8	5	19	19	12	6	73	3	7	1	4	0	0	35	123

BROWN BULLHEAD - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
30	0	0	0	10	0	3	0	0	0	0	0	0	0	0	0	13
40	0	0	0	27	0	6	0	0	0	0	0	0	0	0	0	33
50	0	0	0	5	3	8	0	0	1	0	0	0	0	0	4	13
60	0	0	0	3	0	2	0	0	0	2	2	0	0	0	2	7
70	0	0	0	0	0	0	0	3	0	3	0	0	0	0	0	6
80	0	0	0	0	0	0	0	2	0	4	0	0	0	0	0	6
110	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
190	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
250	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
270	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
280	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2
290	0	2	0	0	0	0	0	0	0	0	0	4	0	0	0	6
300	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	3
310	0	1	1	1	0	0	0	0	0	1	0	2	0	0	1	5
320	0	0	0	0	0	2	0	0	0	3	0	4	0	0	0	9
330	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
340	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
350	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TOTALS	0	7	1	47	4	21	0	6	1	18	2	13	0	0	8	112

BROWN TROUT - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
130	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
160	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
170	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
180	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
190	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
210	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
230	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
250	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
280	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
300	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
310	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0
330	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
380	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
390	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1
400	1	1	0	0	0	0	0	0	0	0	0	1	0	0	1	2
410	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
420	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1
430	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
440	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
490	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
500	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
510	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
520	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1
530	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
540	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1
550	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
570	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
580	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
590	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
600	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	2
610	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
660	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
680	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTALS	2	9	1	5	0	3	7	8	0	0	1	13	0	0	11	38

BURBOT - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
360	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
TOTALS	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0

BURBOT - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
400	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
TOTALS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1

APPENDIX 4.(continued)

CARP - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
520	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
530	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
610	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
630	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2
640	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
760	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	4	0	2	0	1	0	0	0	0	0	0	0	7

CARP - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
30	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
200	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
410	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
470	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
520	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
530	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
540	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
570	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
580	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
590	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
640	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
660	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
670	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
720	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
770	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
TOTALS	0	0	0	3	0	3	0	2	0	2	0	1	1	3	1	14

CHANNEL CATFISH - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
340	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
350	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
460	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
510	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
570	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
610	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	6

CHANNEL CATFISH - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
60	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTALS	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1

APPENDIX 4.(continued)

CHINOOK SALMON - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
90	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
380	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
570	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
820	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
TOTALS	0	1	0	0	0	0	0	1	0	0	0	2	0	0	0	4

COHO SALMON - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
90	2	5	0	0	0	0	0	0	0	0	0	0	0	0	2	5
100	4	23	0	0	0	0	0	0	0	0	0	0	0	0	4	23
110	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	13
140	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
240	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
370	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
390	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
400	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
410	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
420	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTALS	6	41	0	0	0	0	0	3	0	0	0	4	0	0	6	48

COHO SALMON - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
410	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTALS	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1

UNIDENTIFIED COREGONID - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
40	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
50	0	0	0	0	0	0	1	0	8	1	0	1	0	0	9	2
60	0	0	0	0	0	0	3	1	41	6	0	9	1	0	45	16
70	0	0	0	0	0	0	4	6	84	28	0	28	1	0	89	62
80	0	0	0	0	0	0	3	8	31	26	0	22	2	0	36	56
90	0	1	0	0	0	0	0	1	3	3	0	1	0	0	3	6
100	0	3	0	1	0	0	0	0	0	2	0	0	0	0	0	6
110	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	3
120	1	1	4	1	1	1	0	0	0	0	0	0	0	0	6	3
130	0	0	0	1	0	1	0	3	0	0	0	0	0	0	0	5
140	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1
150	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
170	0	4	0	0	0	0	0	2	0	0	0	0	0	0	0	6
180	3	3	1	0	0	0	0	0	0	0	0	0	0	0	4	3
190	6	6	0	1	0	0	0	0	0	0	0	0	0	0	6	7
200	7	6	2	2	0	0	0	0	0	0	0	0	0	0	9	8
210	9	1	1	2	0	0	0	0	0	0	0	0	0	0	10	3
220	1	3	1	2	0	0	0	1	0	0	0	0	0	0	2	6
230	6	3	0	6	0	0	1	0	0	0	0	0	0	0	7	9
240	0	2	2	2	0	0	0	1	0	0	0	0	0	0	2	5
250	2	1	0	2	0	0	0	0	0	0	0	0	0	0	2	3
260	1	1	2	4	0	0	0	0	0	0	0	0	0	0	3	5
270	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	4
280	0	0	1	3	0	0	0	0	0	0	0	0	0	0	1	3
290	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TOTALS	37	36	15	31	1	3	13	25	167	67	0	61	4	0	237	223

EMERALD SHINER - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
80	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
TOTALS	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0

EMERALD SHINER - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
60	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
80	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2	0
TOTALS	0	0	1	0	1	0	0	1	0	0	0	0	0	0	2	1

APPENDIX 4. (continued)

GIZZARD SHAD - Lake Michigan

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
50	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
60	0	0	1	0	0	0	15	2	0	3	0	0	0	0	16	5
70	0	0	0	0	0	0	2	0	0	1	0	0	0	0	2	1
80	0	0	0	0	0	0	4	2	0	1	0	0	0	0	4	3
90	0	0	0	0	0	0	3	2	1	0	2	0	0	0	6	2
100	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
110	0	0	0	0	0	0	1	2	0	3	1	0	0	0	2	5
120	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	1
130	0	0	0	2	0	0	0	1	0	1	0	0	0	0	0	4
140	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
160	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
180	0	0	0	0	0	2	0	1	0	0	0	1	0	0	0	4
190	0	0	0	0	0	2	0	2	0	0	0	2	0	0	0	6
200	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
210	0	0	0	0	0	2	0	2	0	1	0	0	0	0	0	5
220	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3
230	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
350	0	0	0	0	0	1	1	0	0	0	0	1	0	0	1	2
360	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	2
370	0	0	0	0	0	0	0	1	0	0	0	4	0	0	0	5
380	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	9
390	0	0	0	0	0	0	1	0	0	0	0	12	0	0	1	12
400	0	0	0	0	0	0	0	1	0	0	0	10	0	0	0	11
410	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	7
420	0	0	0	0	0	2	1	0	0	0	0	13	0	0	1	15
430	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	6
440	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	9
450	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	8
460	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3
470	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	4
490	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTALS	0	0	1	2	0	14	29	21	2	11	3	91	0	0	35	139

GIZZARD SHAD - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
180	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
360	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
430	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
440	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
460	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
510	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	1	0	2	0	4	0	0	0	0	0	0	0	7

GOLDFISH - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0
TOTALS	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0

GOLDEN REDHORSE - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
470	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TOTALS	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1

GOLDEN SHINER - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
40	0	0	492	294	40	28	0	3	0	0	0	0	0	0	532	325
50	0	8	230	236	155	91	50	19	0	0	1	0	0	0	436	354
60	0	42	1	2	107	25	23	26	0	0	0	0	0	0	131	95
70	0	58	73	29	3	10	1	3	0	0	0	1	0	0	77	101
80	0	33	63	74	18	44	1	1	0	0	0	0	0	0	82	152
90	0	15	21	25	23	44	7	6	0	0	0	0	0	0	51	90
100	0	13	60	8	11	15	1	2	0	0	0	0	0	0	72	38
110	0	6	12	0	2	6	2	1	0	0	0	0	0	0	16	13
120	0	7	4	0	2	0	0	1	0	0	0	0	0	0	6	8
130	0	0	12	2	0	1	3	1	0	0	0	0	0	0	15	4
140	0	0	8	0	0	2	0	0	0	0	0	0	0	0	8	2
150	0	0	2	0	1	1	0	0	0	0	0	0	0	0	3	1
170	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
TOTALS	0	184	978	670	363	267	88	63	0	0	1	1	0	0	1430	1185

GRASS PICKEREL - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL(mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
70	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
100	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
110	0	0	0	1	2	0	0	0	0	0	0	0	0	0	2	1
120	0	0	1	1	0	2	0	0	0	2	0	0	0	0	1	5
130	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
140	0	0	1	0	1	0	0	0	0	0	1	0	0	0	3	0
150	0	0	0	0	3	2	0	0	0	1	3	0	0	0	6	3
160	0	0	0	0	0	0	1	0	0	0	1	0	0	0	2	0
170	0	0	0	0	0	0	0	0	1	1	1	0	0	0	2	1
180	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
190	0	1	0	0	1	0	0	2	0	0	0	0	0	0	1	3
200	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	1
210	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
230	0	3	0	0	0	0	0	0	0	0	1	0	0	0	1	3
240	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	3
250	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
260	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	1
270	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
290	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	7	3	6	9	5	3	4	2	4	7	0	0	0	24	26

JOHNNY DARTER - Lake Michigan

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
20	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
30	0	2	0	0	0	5	0	15	0	4	0	0	0	1	0	27
40	0	5	0	7	0	0	0	33	4	23	1	4	0	0	5	72
50	0	6	1	2	1	5	0	5	0	8	0	1	0	0	2	27
60	9	58	0	2	1	3	0	16	4	14	0	2	0	0	14	95
70	1	34	0	1	0	0	0	4	2	8	0	2	0	0	3	49
80	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1
TOTALS	10	106	1	12	2	15	0	73	11	57	1	9	0	1	25	273

JOHNNY DARTER - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL(mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
10	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
20	0	2	1	0	0	0	0	0	0	0	0	0	0	0	1	2
30	0	0	2	5	0	0	0	0	0	0	0	0	0	0	2	5
40	0	3	11	9	2	7	0	1	1	0	0	2	0	0	14	22
50	2	1	2	3	7	1	1	4	1	5	2	9	0	0	15	23
60	1	2	0	0	2	1	0	0	1	4	4	5	0	0	8	12
70	0	1	0	1	0	0	0	1	1	0	0	0	0	0	1	3
TOTALS	3	9	16	18	11	9	1	6	4	9	6	17	0	0	41	68

APPENDIX 4. (continued)

LAKE CHUBSUCKER - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
50	0	0	3	3	0	0	0	0	0	0	0	0	0	0	3	3
60	0	1	0	0	1	1	0	0	0	0	0	0	0	0	1	2
70	0	3	0	0	1	0	0	0	0	0	2	0	0	0	3	3
80	1	5	0	0	0	0	1	1	1	2	0	1	0	0	3	9
90	0	3	0	0	0	0	1	0	0	1	0	0	0	0	1	4
100	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1
110	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
130	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
140	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1
160	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2
170	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
180	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
190	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1
210	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
TOTALS	1	17	4	5	2	1	2	1	1	5	5	2	0	0	15	31

LAKE HERRING - Lake Michigan

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
400	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1

LAKE STURGEON - Lake Michigan

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
580	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1

APPENDIX 4. (continued)

LONGNOSE DACE - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
50	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
60	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
TOTALS	0	0	0	0	0	0	0	0	1	0	0	2	0	0	1	2

LONGNOSE DACE - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
40	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
TOTALS	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1

LONGNOSE SUCKER - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
250	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
420	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0
430	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
440	0	0	0	2	2	0	0	0	0	0	0	0	0	0	2	2
450	0	0	0	3	4	0	0	2	0	0	0	0	0	0	4	5
460	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
470	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	3
480	0	0	0	2	2	0	0	0	0	0	0	0	0	0	2	2
490	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
500	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
540	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	4
550	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
570	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0
TOTALS	0	0	0	16	12	1	0	6	0	0	0	1	0	0	12	24

LAKE WHITEFISH - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
260	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
330	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
340	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
350	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
370	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
390	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
420	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
450	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
470	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	8	0	2	0	0	0	1	0	0	0	0	0	0	0	11

LARGEMOUTH BASS - Pigeon Lake

SPECIES= LB GEAR= FIELD SAMPLES STATION= PIGEON LAKE

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	157	43	0	0	0	0	0	0	0	0	0	0	0	0	157	43
30	52	17	1	0	0	0	0	0	0	0	0	0	0	0	53	17
40	0	0	4	3	2	1	0	0	0	0	0	0	0	0	6	4
50	0	0	36	35	4	4	0	0	1	0	0	0	0	0	41	39
60	0	0	23	31	24	28	4	1	0	0	6	0	0	0	57	60
70	0	0	22	7	16	19	9	16	3	4	11	0	0	0	61	46
80	0	0	5	3	9	10	38	12	0	4	10	2	0	0	62	31
90	0	1	0	1	7	3	13	3	3	0	10	3	0	0	33	11
100	1	0	0	0	2	2	4	0	0	0	3	2	0	0	10	4
110	1	0	0	0	0	1	3	0	0	0	1	2	0	0	5	3
120	0	0	0	2	0	0	0	0	0	0	1	1	0	0	1	3
130	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2	0
150	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
160	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
170	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2
210	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
330	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
350	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
370	0	1	0	0	1	0	1	0	0	0	0	0	0	0	2	1
550	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
TOTALS	211	62	91	83	66	70	75	32	8	8	44	10	0	0	495	265

APPENDIX 4. (continued)

LAKE TROUT - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
120	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
140	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
150	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
160	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
330	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
420	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
430	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
490	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
530	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
540	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	3
550	0	0	0	2	0	0	0	1	0	0	1	0	0	0	1	3
580	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
610	0	0	0	3	0	0	0	1	0	0	0	0	0	0	0	4
620	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
630	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	4
640	0	0	0	1	0	0	1	4	0	0	0	0	0	0	1	5
650	0	0	0	2	0	0	2	2	0	0	0	0	0	0	2	4
660	0	0	0	2	0	0	0	7	0	0	0	0	0	0	0	9
670	0	0	0	3	0	0	2	3	0	0	0	0	0	0	2	6
680	0	0	0	3	0	0	0	9	0	0	0	3	0	0	0	15
690	0	0	0	6	0	0	1	4	0	1	0	1	0	0	1	12
700	1	0	0	3	0	0	4	2	0	0	1	3	0	0	6	8
710	0	0	0	9	0	0	1	10	0	0	0	1	0	0	1	20
720	1	0	0	3	0	0	1	7	0	0	0	2	0	0	2	12
730	0	0	0	2	0	0	2	8	0	0	0	1	0	0	2	11
740	0	0	0	4	0	0	2	8	0	0	0	1	0	0	2	13
750	0	0	0	4	0	1	2	5	0	0	0	0	0	0	2	10
760	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
770	0	0	0	0	0	0	1	5	0	0	0	0	0	0	1	5
780	0	0	0	2	0	0	1	4	0	0	0	1	0	0	1	7
790	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
800	0	0	0	2	0	0	0	3	0	0	0	0	0	0	0	5
810	0	0	0	0	0	0	1	2	0	0	0	0	0	0	1	2
820	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
830	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
TOTALS	3	1	0	56	0	1	22	98	0	1	2	16	1	0	28	173

LAKE TROUT - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
640	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1

APPENDIX 4. (continued)

MOTTLED SCULPIN - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
40	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
60	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
90	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TOTALS	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0

MOTTLED SCULPIN - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
80	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTALS	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1

NINESPINE STICKLEBACK - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
30	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	3
40	0	1	0	2	0	0	0	0	0	1	0	0	0	0	0	4
50	4	16	2	7	0	5	1	2	0	1	0	1	0	0	7	32
60	7	39	1	2	0	5	0	6	0	0	0	0	0	0	8	52
70	4	16	1	1	0	1	2	0	0	0	0	0	0	0	7	18
TOTALS	15	72	4	12	0	11	3	11	0	3	0	2	0	0	22	111

NINESPINE STICKLEBACK - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
60	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TOTALS	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

APPENDIX 4.(continued)

NORTHERN PIKE - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
40	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
70	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
80	2	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0
100	0	0	1	2	0	0	0	0	0	0	0	0	0	0	1	2
110	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
120	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
130	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
150	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
160	0	0	0	3	1	0	0	0	0	0	0	0	0	0	1	3
170	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	2
180	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
210	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	1
220	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
230	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
250	0	0	0	0	0	0	2	0	0	1	0	0	0	0	2	1
260	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
300	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
310	2	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0
330	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
360	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
390	1	0	0	1	0	0	0	0	1	0	1	0	0	0	3	1
430	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
440	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
460	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
470	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2	0
480	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
490	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
510	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
520	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3	0
530	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1
550	1	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0
560	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
580	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
600	0	0	0	0	0	0	0	0	0	0	0	1	3	1	3	2
610	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1
620	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
630	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1
640	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
650	0	1	0	0	1	0	1	0	0	0	1	0	0	0	3	1
660	0	0	0	0	0	0	0	1	0	1	0	1	1	0	1	3
670	0	0	0	0	0	1	0	0	0	0	0	0	2	0	2	1
690	0	0	1	0	0	0	0	0	0	0	0	0	1	0	2	0
700	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2
710	0	0	0	0	0	0	0	0	1	0	1	0	1	0	3	0
720	0	0	0	1	1	0	0	0	0	0	0	1	1	0	2	2
730	0	0	0	0	0	0	0	0	1	0	2	0	0	0	3	0
740	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
750	1	0	0	0	1	0	0	1	0	0	0	2	0	0	2	3
760	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
780	0	0	0	0	1	0	0	0	0	0	1	0	1	0	3	0
790	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
810	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
820	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
830	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
840	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
870	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
890	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
930	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
TOTALS	9	5	6	11	11	5	7	5	4	3	17	12	14	4	68	45

APPENDIX 4.(continued)

PIRATE PERCH - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
70	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TOTALS	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1

PUMPKINSEED - Lake Michigan

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
40	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
TOTALS	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0

PUMPKINSEED - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
30	0	0	1	0	1	0	0	1	1	3	1	1	0	0	4	5
40	0	1	4	0	8	6	1	8	4	8	0	2	0	0	17	25
50	0	3	1	0	6	4	0	4	2	4	11	9	0	0	20	24
60	1	3	0	1	0	2	1	1	4	4	11	4	0	0	17	15
70	1	2	0	3	0	4	1	0	0	1	0	0	0	0	2	10
80	0	0	5	3	0	3	0	0	0	0	0	0	0	0	5	6
90	0	1	4	1	1	3	0	0	1	0	0	0	0	0	6	5
100	2	2	0	1	1	0	3	0	1	0	0	0	0	0	7	3
110	0	1	0	0	1	5	0	1	0	0	0	0	0	0	1	7
120	2	2	1	5	1	2	0	0	2	2	3	0	0	0	9	11
130	0	1	0	3	0	0	1	0	0	0	0	0	0	0	1	4
140	0	1	0	2	0	2	0	1	1	0	1	1	0	0	2	7
150	0	0	1	1	0	2	1	0	0	0	0	0	0	0	2	3
160	0	3	0	1	1	1	0	0	0	0	1	0	0	0	2	5
170	0	4	0	0	0	0	1	0	0	0	0	0	0	0	1	4
180	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
200	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	6	25	17	22	20	34	9	16	16	22	28	17	0	0	96	136

APPENDIX 4. (continued)

QUILLBACK - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
470	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
TOTALS	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0

RAINBOW TROUT - Lake Michigan

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
300	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
480	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
510	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
520	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
540	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
550	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
560	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
590	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TOTALS	0	0	0	0	0	0	0	1	0	3	0	4	0	0	0	8

RAINBOW TROUT - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
510	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
580	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
TOTALS	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1

APPENDIX 4. (continued)

RAINBOW SMELT - Lake Michigan

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
20	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2
30	0	0	23	54	1393	1261	8	101	9	1	2	1	0	1	1435	1419
40	0	0	46	250	2442	2156	512	1344	54	93	2	8	1	6	3057	3857
50	6	7	0	0	3	3	155	322	76	97	12	35	89	79	341	543
60	56	93	6	10	3	2	5	14	18	3	4	6	282	158	374	286
70	147	122	16	4	3	8	3	0	0	0	0	0	97	15	266	149
80	259	70	42	3	4	7	4	2	0	0	0	0	2	1	311	83
90	112	47	38	2	3	8	11	6	0	0	0	0	0	0	164	63
100	80	12	29	1	3	12	10	1	0	0	0	0	0	0	122	26
110	10	0	17	0	11	23	17	4	1	0	0	0	0	0	56	27
120	20	1	6	0	26	18	27	9	1	0	0	0	0	0	80	28
130	13	0	0	0	4	5	19	12	0	0	0	0	0	0	36	17
140	2	1	0	0	2	5	7	14	0	0	0	0	0	0	11	20
150	1	0	4	0	6	0	15	23	0	0	0	0	0	0	26	23
160	1	1	1	0	1	2	14	13	0	0	0	0	0	0	17	16
170	1	0	0	1	1	2	13	9	0	0	0	0	0	0	15	12
180	1	0	0	0	1	0	3	2	0	0	0	0	0	0	5	2
190	0	0	0	0	0	0	2	0	0	0	0	0	0	1	2	1
200	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
210	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
220	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1
250	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
TOTALS	711	354	228	326	3906	3512	827	1879	159	194	20	50	471	261	6322	6576

RAINBOW SMELT - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
30	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
60	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	3
80	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
130	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
190	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
TOTALS	0	0	1	3	0	1	0	1	0	0	1	0	0	0	2	5

APPENDIX 4.(continued)

ROCK BASS - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
30	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
40	1	1	0	1	0	0	0	0	1	0	0	0	0	0	2	2
50	2	5	4	11	0	2	0	0	0	0	0	0	0	0	6	18
60	1	6	0	4	2	7	0	0	0	0	0	0	0	0	3	17
70	0	3	0	15	0	7	0	1	0	0	0	0	0	0	0	26
80	0	2	1	25	1	8	0	0	0	0	0	0	0	0	2	35
90	1	0	1	8	2	8	0	1	0	0	0	0	0	0	4	17
100	0	1	0	0	0	3	0	4	0	1	0	0	0	0	0	9
110	0	1	0	1	0	1	1	1	0	0	0	1	0	0	1	5
120	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
130	0	1	0	1	1	1	0	0	0	0	0	0	0	0	1	3
140	1	0	1	1	0	1	0	0	0	1	0	0	0	0	2	3
150	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	4
160	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	3
170	2	1	0	0	0	0	0	0	0	1	0	1	0	0	2	3
180	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
190	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
200	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TOTALS	8	24	8	69	6	40	1	8	1	5	0	3	0	0	24	149

ROUND WHITEFISH - Lake Michigan

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
140	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
160	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
360	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
430	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
450	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
460	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
470	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
480	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
TOTALS	0	0	0	1	0	0	1	2	0	1	2	0	1	0	4	4

APPENDIX 4.(continued)

SHORTHEAD REDHORSE - Lake Michigan

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
440	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1

SILVER REDHORSE - Lake Michigan

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
60	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
480	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
490	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
510	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
520	0	0	0	2	0	0	1	0	0	0	0	0	0	0	1	2
540	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
560	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
580	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
590	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
600	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	6	0	2	3	0	0	0	1	0	0	0	4	8

APPENDIX 4.(continued)

SLIMY SCULPIN - Lake Michigan

LENGTH INTERVAL(mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
40	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	4
50	0	5	2	0	0	0	0	0	0	0	0	0	0	0	2	5
60	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	2
70	0	2	0	0	0	0	0	0	0	0	0	0	2	2	2	4
80	0	1	0	0	0	0	0	0	0	1	0	0	4	4	4	6
90	0	0	0	0	0	0	0	0	0	2	0	1	1	9	1	12
100	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
TOTALS	0	12	3	2	0	0	0	0	0	3	0	1	7	16	10	34

SLIMY SCULPIN - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
40	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
50	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
60	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
70	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2
80	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	3
90	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TOTALS	0	0	0	0	0	1	0	1	0	5	0	2	0	0	0	9

SMALLMOUTH BASS - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
160	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
170	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
410	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
430	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
440	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
TOTALS	1	2	0	0	0	0	0	0	0	0	2	0	0	0	3	2

SPOTTAIL SHINER - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
30	0	0	0	1	238	0	37	0	1	0	0	2	0	0	276	3
40	1	8	4	60	577	2	750	44	20	16	0	10	3	23	1355	163
50	1	13	17	27	16	7	1613	89	47	177	4	21	54	47	1752	381
60	0	17	71	116	68	34	665	19	3	6	0	4	13	11	820	207
70	3	7	47	191	65	126	94	4	2	10	0	5	1	4	212	347
80	1	10	10	86	1	51	275	7	3	12	0	6	3	7	293	179
90	1	28	13	48	1	47	54	5	0	8	0	3	1	1	70	140
100	6	96	20	166	1	30	4	10	0	14	0	0	0	3	31	319
110	9	177	17	168	6	48	49	94	0	36	0	7	3	7	84	537
120	17	96	13	97	36	71	57	108	0	11	0	18	6	8	129	409
130	8	56	2	31	6	12	30	10	0	0	0	7	1	1	47	117
140	0	4	0	1	1	0	0	0	0	0	0	1	1	0	2	6
TOTALS	47	512	215	992	1016	428	3628	390	76	290	4	84	86	112	5072	2808

SPOTTAIL SHINER - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
10	0	0	0	0	4	0	0	0	0	0	0	0	0	0	4	0
20	0	0	12	25	130	41	0	0	1	2	0	0	0	0	143	68
30	0	0	435	47	185	80	355	474	43	18	0	0	0	0	1018	619
40	0	0	865	144	55	31	275	1077	39	12	3	1	0	0	1237	1265
50	0	2	13	7	0	1	42	104	0	0	4	1	0	0	59	115
60	0	1	4	1	0	0	0	5	0	0	0	0	0	0	4	7
70	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	3
110	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2
120	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
130	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
140	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	3	1329	228	374	153	672	1661	83	35	7	2	0	0	2465	2082

APPENDIX 4.(continued)

TADPOLE MADTOM - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
30	0	0	0	0	0	1	1	0	0	2	2	1	0	0	3	4
40	0	1	0	0	0	0	2	5	0	2	5	0	0	0	7	8
50	1	5	0	1	0	0	0	1	0	1	1	2	0	0	2	10
60	1	0	1	6	0	0	1	0	0	0	1	0	0	0	4	6
70	0	0	0	2	0	0	2	0	0	1	0	0	0	0	2	3
80	0	2	0	0	0	0	1	0	1	1	0	0	0	0	2	3
90	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
TOTALS	2	8	1	9	0	1	7	7	1	7	9	3	0	0	20	35

TROUT-PERCH - Lake Michigan

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
20	0	0	0	0	0	0	0	5	0	1	0	1	0	0	0	7
30	0	8	0	0	0	0	0	3	0	1	0	2	0	0	0	14
40	10	40	0	5	0	0	0	1	0	0	0	0	0	0	10	46
50	10	49	0	45	0	4	0	0	0	0	0	0	0	0	10	98
60	9	26	8	102	6	14	0	2	0	0	0	0	0	0	23	144
70	0	14	2	30	15	12	4	26	2	0	0	0	0	1	23	83
80	9	44	0	6	1	6	4	46	3	1	0	0	0	1	17	104
90	13	37	1	5	1	11	0	19	1	1	0	0	0	0	16	73
100	1	20	1	5	0	10	1	6	0	5	0	0	1	0	4	46
110	2	10	0	5	1	17	1	9	0	9	0	10	0	0	4	60
120	2	7	0	5	0	18	0	6	0	4	0	17	0	1	2	58
130	3	11	0	1	0	11	0	0	0	6	0	5	1	0	4	34
140	0	0	0	0	0	2	0	0	0	2	0	4	0	0	0	8
150	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	3
160	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
TOTALS	59	267	12	209	24	105	10	123	6	30	0	43	2	3	113	780

TROUT-PERCH - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
110	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
120	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	3
TOTALS	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	4

APPENDIX 4.(continued)

<u>WARMOUTH - Pigeon Lake</u>

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
150	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2
160	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
170	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
190	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
TOTALS	0	1	1	2	0	0	0	2	0	0	0	0	0	0	1	5

APPENDIX 4. (continued)

WHITE SUCKER - Lake Michigan

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
70	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
240	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
250	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
260	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
270	0	0	0	2	2	0	0	0	0	0	0	0	0	0	2	2
280	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0	4
290	0	0	0	2	1	0	0	0	0	0	0	0	0	0	1	2
300	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
310	1	0	0	4	0	1	0	0	0	0	0	0	0	0	1	5
320	0	0	0	0	2	1	2	4	0	0	0	0	0	0	4	5
330	0	0	0	0	0	2	0	5	0	0	0	0	0	0	0	7
340	0	0	0	0	5	4	0	7	0	0	0	1	0	0	5	12
350	0	0	0	0	0	2	1	2	0	0	0	0	0	0	1	4
360	0	0	0	0	0	2	5	3	0	0	0	0	0	0	5	5
370	0	0	0	0	0	4	2	3	0	0	0	0	0	0	2	7
380	0	0	0	0	0	3	2	0	0	0	0	1	0	0	2	4
390	1	0	0	2	2	8	1	3	0	0	0	0	0	0	4	13
400	0	0	0	0	2	3	2	4	0	0	0	0	0	0	4	7
410	0	0	0	0	4	2	1	2	0	0	0	1	0	0	5	5
420	0	1	0	0	4	11	1	2	0	0	0	0	0	0	5	14
430	0	0	0	10	2	5	2	4	0	0	0	0	0	0	4	19
440	0	0	0	2	4	6	1	2	0	0	0	0	0	0	5	10
450	0	0	0	1	4	6	1	2	0	0	0	0	1	0	6	9
460	0	0	0	4	6	0	2	0	0	0	0	0	0	0	8	4
470	0	0	0	3	4	7	2	3	0	0	0	0	0	0	6	13
480	0	0	0	2	4	3	3	1	0	0	0	0	0	0	7	6
490	0	0	0	2	6	2	2	1	0	0	0	0	0	0	8	5
500	0	0	0	1	4	5	2	1	0	0	0	0	0	0	6	7
510	0	0	0	4	0	2	0	1	0	0	0	1	0	0	0	8
520	0	0	0	2	2	1	0	1	0	0	0	0	0	0	2	4
530	0	0	0	0	2	2	0	0	0	0	0	0	0	0	2	2
540	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
560	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0
570	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2
580	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
590	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0
TOTALS	2	1	0	51	64	87	32	52	0	0	0	4	1	0	99	195

APPENDIX 4. (continued)

WHITE SUCKER - Pigeon Lake

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
260	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
270	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2
310	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
420	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
430	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
440	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	1
460	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0
480	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
490	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	1
540	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0
550	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
560	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
580	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
TOTALS	0	0	0	4	0	2	2	0	1	4	0	2	3	0	6	12

APPENDIX 4.(continued)

YELLOW BULLHEAD - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
20	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
30	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	4
40	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3
50	0	0	0	0	0	4	0	0	0	2	0	1	0	0	0	7
60	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
90	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
100	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
120	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
210	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
220	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
230	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
250	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
260	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	3
270	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
280	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	2
300	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
320	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TOTALS	1	2	0	1	0	15	0	0	0	13	0	3	0	0	1	34

APPENDIX 4. (continued)

YELLOW PERCH - Lake Michigan

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
30	0	0	1	0	5	2	0	0	0	0	0	0	0	0	6	2
40	0	0	1	3	37	10	1	0	0	1	0	1	0	1	39	16
50	0	0	0	0	6	1	33	0	0	0	0	1	5	2	44	4
60	0	0	0	1	4	0	186	4	1	0	0	1	7	17	198	23
70	0	0	0	0	0	0	41	1	0	2	0	2	11	6	52	11
80	0	3	0	0	0	0	14	0	0	0	0	0	0	1	14	4
90	2	4	0	0	0	0	3	0	0	0	0	0	2	0	7	4
100	0	0	1	1	1	0	2	2	0	0	0	0	0	0	4	3
110	0	0	0	5	0	0	1	0	0	0	0	0	0	0	1	5
120	0	0	1	5	1	1	0	0	0	0	0	0	0	0	2	6
130	0	0	0	1	1	5	0	0	0	0	0	0	0	0	1	6
140	1	0	1	1	0	2	3	2	0	0	0	0	0	0	5	5
150	3	2	0	1	3	3	8	3	0	0	1	1	0	1	15	11
160	27	3	5	2	3	2	12	5	0	1	0	4	0	0	47	17
170	15	5	7	5	9	5	5	3	0	1	0	3	0	0	36	22
180	6	4	3	7	67	7	9	3	0	0	0	1	0	0	85	22
190	2	1	6	15	38	10	22	6	0	0	0	1	0	0	68	33
200	2	1	7	10	36	7	20	5	0	0	1	6	0	0	66	29
210	2	0	3	4	56	9	21	5	0	0	1	2	0	0	83	20
220	0	1	5	2	20	8	9	6	0	0	1	5	0	0	35	22
230	1	0	6	9	6	4	3	4	0	0	0	5	0	0	16	22
240	1	1	8	2	23	8	5	2	0	0	0	5	0	0	37	18
250	0	1	4	2	6	3	4	2	0	0	0	1	0	0	14	9
260	1	0	3	4	9	3	2	0	0	0	0	0	1	0	16	7
270	1	0	0	0	11	2	1	0	0	0	0	0	0	0	13	2
280	0	0	3	0	8	2	3	0	1	0	0	0	0	0	15	2
290	0	0	1	0	4	0	2	0	0	0	0	0	0	0	7	0
310	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
320	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
330	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TOTALS	66	26	67	80	354	94	410	53	2	5	4	39	26	28	929	325

APPENDIX 4.(continued)

YELLOW PERCH - Pigeon Lake

LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL(mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
20	12	5	0	0	0	0	0	0	0	0	0	0	0	0	12	5
30	51	14	0	0	0	0	0	0	0	0	0	0	0	0	51	14
40	0	0	24	13	0	0	0	0	2	0	1	0	0	0	27	13
50	0	0	93	175	2	8	0	1	0	0	0	0	0	0	95	184
60	0	0	104	312	65	77	1	11	0	11	1	10	0	0	171	421
70	0	0	6	74	30	81	12	38	7	10	2	13	0	0	57	216
80	0	0	0	1	16	9	83	54	15	7	6	15	0	0	120	86
90	0	1	0	0	0	0	35	16	13	16	4	9	0	0	52	42
100	0	0	0	0	0	0	1	1	5	1	7	1	1	0	14	3
110	1	1	0	1	0	0	0	2	1	0	3	0	0	0	5	4
120	0	2	4	5	0	1	0	0	1	1	0	0	0	0	5	9
130	10	16	4	0	1	5	1	0	1	2	5	1	0	0	22	24
140	39	51	8	9	2	2	3	1	2	2	11	2	0	0	65	67
150	26	32	8	26	10	10	10	1	7	2	7	7	0	0	68	78
160	22	36	3	20	14	5	26	5	4	0	11	8	0	0	80	74
170	5	11	4	16	10	9	5	2	4	4	18	3	0	0	46	45
180	7	7	9	12	11	13	25	6	5	7	15	3	0	0	72	48
190	2	1	1	7	6	3	15	5	4	1	27	4	0	1	55	22
200	1	0	0	0	3	3	12	3	5	1	9	4	1	0	31	11
210	0	0	0	1	1	1	3	3	2	1	5	1	1	1	12	8
220	1	0	0	0	0	0	2	2	1	0	6	2	0	0	10	4
230	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
240	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1
250	0	1	0	0	0	0	0	0	0	0	1	0	1	0	2	1
260	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
270	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
320	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
340	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TOTALS	179	178	268	673	171	227	236	151	79	67	140	84	4	2	1077	1382

APPENDIX 5

APPENDIX 5. Monthly length-frequency distribution of fish caught in Lake Michigan and Pigeon Lake during 1977 in the vicinity of the J. H. Campbell Plant, Ottawa County, Michigan. Distributions were segregated by gear type.

Alewife Lake Michigan — SEINES

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	106	0	0	0	0	0	0	0	0	0	0	0	106	0
30	0	0	430	1089	3117	420	1497	6	965	67	168	57	0	0	6177	1639
40	0	0	1111	2239	1646	4800	4152	64	1465	164	822	199	0	0	9196	7466
50	0	0	55	5	40	826	2259	629	160	24	322	42	0	0	2836	1526
60	0	0	0	0	7	232	4156	298	0	3	25	2	0	0	4188	535
70	0	0	0	1	0	82	1483	100	4	2	3	2	0	0	1490	187
80	0	0	3	1	0	1	139	47	0	1	1	0	0	0	143	50
90	0	32	14	1	0	2	7	32	0	0	0	0	0	0	21	67
100	0	63	14	0	0	3	0	5	0	0	0	0	0	0	14	71
110	0	10	2	1	0	0	0	0	0	0	0	0	0	0	2	11
120	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4
130	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5
140	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	9
150	0	50	0	0	0	10	0	0	0	0	0	0	0	0	0	60
160	0	91	2	0	0	19	0	1	0	0	0	0	0	0	2	111
170	0	185	0	1	0	12	0	1	0	0	0	0	0	0	0	199
180	0	285	0	1	0	0	0	3	0	1	0	0	0	0	0	290
190	0	261	0	1	0	1	0	0	0	0	0	0	0	0	0	263
200	0	111	0	0	0	0	0	1	0	0	0	0	0	0	0	112
210	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3
220	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	1110	1737	3340	4810	6408	13693	1187	2594	262	1341	302	0	0	24175	12609

Alewife Lake Michigan — TRAWLS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
10	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
20	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2
30	0	0	0	0	542	87	2	33	155	22	1	1	0	0	700	143
40	0	0	0	0	1351	21	0	43	844	164	11	87	0	0	2206	315
50	0	0	0	0	64	0	1	18	602	412	636	173	0	0	1303	603
60	0	0	0	0	36	0	120	7	1611	888	2224	27	0	0	3991	922
70	0	0	0	0	1	1	66	1	689	632	1440	2	0	0	2196	636
80	4	0	0	0	0	0	52	1	94	211	120	0	0	0	270	212
90	6	0	2	0	0	0	27	0	22	183	41	0	0	0	98	183
100	3	0	0	0	0	0	13	0	0	27	2	0	0	0	18	27
110	3	0	2	0	0	0	0	0	0	0	0	0	0	0	5	0
120	4	1	0	0	0	0	0	0	0	0	0	0	0	0	4	1
130	1	0	0	0	0	0	6	0	0	0	0	0	0	0	7	0
140	17	0	8	0	0	0	9	1	0	0	0	0	0	0	34	1
150	58	3	37	0	1	3	30	1	0	0	0	0	0	0	126	7
160	79	3	56	0	5	3	94	3	0	0	0	0	0	0	234	9
170	191	15	51	2	6	5	149	1	0	0	0	0	0	0	397	23
180	186	13	19	0	1	5	86	0	0	0	0	0	0	0	292	18
190	91	21	8	0	0	5	27	0	0	0	0	0	0	0	126	26
200	34	2	6	0	0	0	3	0	0	0	0	0	0	0	43	2
210	0	2	2	0	0	0	0	0	0	0	0	0	0	0	2	2
220	5	1	0	0	0	0	0	0	0	0	0	0	0	0	5	1
TOTALS	682	61	191	4	2007	130	685	109	4017	2540	4475	290	0	0	12057	3134

APPENDIX 5. (continued)

Alewife Lake Michigan

BOTTOM GILL NETS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
100	0	0	0	1	0	0	9	1	0	0	0	0	0	0	9	2
110	0	0	0	0	2	0	4	0	0	0	0	0	0	0	6	0
120	0	0	0	0	2	0	4	0	0	0	0	0	0	0	6	0
130	2	0	1	0	3	1	1	0	0	0	0	0	0	0	7	1
140	0	0	0	0	1	1	1	0	0	0	0	0	0	0	2	1
150	0	0	43	3	17	5	37	1	0	0	0	0	0	0	97	9
160	9	0	104	10	95	19	165	21	0	0	0	0	0	0	373	50
170	27	0	68	15	93	31	141	11	0	0	0	0	0	0	329	57
180	19	0	52	11	22	13	32	1	0	0	0	1	0	0	125	26
190	5	0	13	3	13	1	6	0	0	0	0	0	0	0	37	4
200	1	0	2	0	5	0	0	0	0	0	0	0	0	0	8	0
210	1	0	1	0	1	0	0	0	0	0	0	0	0	0	3	0
220	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
TOTALS	67	0	284	43	254	71	400	35	0	0	0	1	0	0	1005	150

Alewife Lake Michigan

SURFACE GILL NET

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
90	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
100	0	0	0	0	0	0	1	33	0	0	0	0	0	0	1	33
110	0	0	0	2	0	0	0	3	0	0	0	0	0	0	0	5
120	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2
130	3	0	0	1	0	0	0	1	0	0	0	0	0	0	3	2
140	0	0	0	0	0	0	2	11	0	0	0	0	0	0	2	11
150	3	0	1	24	0	0	6	28	0	0	0	0	0	0	10	52
160	76	0	20	61	0	0	21	35	0	0	0	0	0	0	117	96
170	80	0	26	59	0	0	6	39	0	0	0	0	0	0	112	98
180	83	0	13	33	0	0	5	3	0	0	0	0	0	0	101	36
190	29	0	0	6	0	0	0	3	0	0	0	0	0	0	29	9
200	3	0	0	1	0	0	0	3	0	0	0	0	0	0	3	4
210	1	0	2	1	0	0	0	0	0	0	0	0	0	0	3	1
220	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
TOTALS	278	0	62	189	0	0	41	164	0	0	0	0	0	0	381	353

APPENDIX 5. (continued)

Rainbow smelt Lake Michigan — BOTTOM GILL NETS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
120	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
130	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
140	0	0	0	0	0	1	1	2	0	0	0	0	0	0	1	3
150	0	0	2	0	2	0	8	3	0	0	0	0	0	0	12	3
160	0	0	1	0	0	2	11	6	0	0	0	0	0	0	12	8
170	0	0	0	0	0	1	10	3	0	0	0	0	0	0	10	4
180	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
190	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0
210	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
220	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1
250	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
TOTALS	0	0	3	0	2	5	35	18	0	0	0	0	0	0	40	23

Rainbow smelt Lake Michigan — SURFACE GILL NETS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
130	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
140	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	4
150	0	0	0	0	0	0	1	16	0	0	0	0	0	0	1	16
160	0	0	0	0	0	0	1	3	0	0	0	0	0	0	1	3
170	0	0	0	1	0	0	2	5	0	0	0	0	0	0	2	6
TOTALS	0	0	0	1	0	0	4	30	0	0	0	0	0	0	4	31

APPENDIX 5. (continued)

Rainbow smelt Lake Michigan

SEINES

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
30	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2
40	0	0	1	2	0	0	0	0	1	0	0	0	0	0	2	2
50	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	3
60	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2
70	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3
80	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5
90	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	7
100	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3
110	0	0	0	0	0	4	0	0	1	0	0	0	0	0	1	4
120	0	0	0	0	0	9	0	3	0	0	0	0	0	0	0	12
130	0	0	0	0	0	3	0	7	0	0	0	0	0	0	0	10
140	0	0	0	0	0	0	2	8	0	0	0	0	0	0	2	8
150	0	0	0	0	0	0	1	3	0	0	0	0	0	0	1	3
160	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	4
170	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
TOTALS	0	19	1	4	0	16	3	26	2	3	0	1	0	0	6	69

Rainbow smelt Lake Michigan

TRAWLS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2
30	0	0	23	53	1393	1261	8	101	9	0	2	1	0	1	1435	1417
40	0	0	45	248	2442	2156	512	1344	53	93	2	8	1	6	3055	3855
50	6	7	0	0	3	3	155	322	76	95	12	34	89	79	341	540
60	56	92	6	9	3	2	5	14	18	3	4	6	282	158	374	284
70	147	119	16	4	3	8	3	0	0	0	0	0	97	15	266	146
80	259	65	42	3	4	7	4	2	0	0	0	0	2	1	311	78
90	112	40	38	2	3	8	11	6	0	0	0	0	0	0	164	56
100	80	9	29	1	3	12	10	1	0	0	0	0	0	0	122	23
110	10	0	17	0	11	19	17	4	0	0	0	0	0	0	55	23
120	20	1	6	0	26	8	27	6	1	0	0	0	0	0	80	15
130	13	0	0	0	4	2	18	3	0	0	0	0	0	0	35	5
140	2	1	0	0	2	4	4	0	0	0	0	0	0	0	8	5
150	1	0	2	0	4	0	5	1	0	0	0	0	0	0	12	1
160	1	1	0	0	1	0	2	0	0	0	0	0	0	0	4	1
170	1	0	0	0	1	1	1	0	0	0	0	0	0	0	3	1
180	1	0	0	0	1	0	3	0	0	0	0	0	0	0	5	0
190	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
200	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
TOTALS	711	335	224	321	3904	3491	785	1805	157	191	20	49	471	261	6272	6453

APPENDIX 5. (continued)

Spottail shiner Lake Michigan

SEINES

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
30	0	0	0	1	238	0	37	0	1	0	0	0	0	0	276	1
40	0	5	4	60	577	2	750	44	16	0	0	4	0	0	1347	115
50	0	7	17	27	16	7	1611	89	19	1	4	5	0	0	1667	136
60	0	15	71	116	68	34	664	17	0	1	0	3	0	0	803	186
70	0	6	47	191	65	125	92	1	1	4	0	1	0	0	205	328
80	0	9	10	86	1	51	271	3	2	4	0	5	0	0	284	158
90	0	25	13	48	1	47	53	0	0	2	0	1	0	0	67	123
100	1	79	20	162	0	29	0	1	0	1	0	0	0	0	21	272
110	0	165	17	151	0	23	0	1	0	0	0	0	0	0	17	340
120	0	71	13	81	0	13	0	0	0	0	0	0	0	0	13	165
130	0	50	2	27	0	1	0	0	0	0	0	1	0	0	2	79
140	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	3
TOTALS	1	434	215	951	966	332	3478	156	39	13	4	20	0	0	4703	1906

Spottail shiner Lake Michigan

TRAWLS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
30	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
40	0	3	0	0	0	0	0	0	4	16	0	6	3	23	7	48
50	1	6	0	0	0	0	2	0	28	176	0	16	54	47	85	245
60	0	2	0	0	0	0	1	2	3	5	0	1	13	11	17	21
70	3	1	0	0	0	1	2	3	1	6	0	4	1	4	7	19
80	1	1	0	0	0	0	4	4	1	8	0	1	3	7	9	21
90	1	3	0	0	0	0	1	5	0	6	0	2	1	1	3	17
100	5	17	0	0	1	0	0	4	0	13	0	0	0	3	6	37
110	3	12	0	0	0	0	0	6	0	36	0	0	3	7	6	61
120	3	25	0	0	0	0	0	4	0	11	0	1	6	8	9	49
130	3	6	0	0	0	0	0	0	0	0	0	0	1	1	4	7
140	0	2	0	0	0	0	0	0	0	0	0	0	1	0	1	2
TOTALS	20	78	0	0	1	1	10	28	37	277	0	33	86	112	154	529

Spottail shiner Lake Michigan

BOTTOM GILL NETS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
40	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
100	0	0	0	4	0	1	4	5	0	0	0	0	0	0	4	10
110	6	0	0	16	6	25	49	87	0	0	0	7	0	0	61	135
120	14	0	0	16	36	58	57	104	0	0	0	17	0	0	107	195
130	5	0	0	4	6	11	30	10	0	0	0	6	0	0	41	31
140	0	0	0	0	1	0	0	1	0	0	0	1	0	0	1	2
150	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
180	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
TOTALS	26	0	0	40	49	95	140	209	0	0	0	31	0	0	215	375

Spottail shiner Lake Michigan

SURFACE GILL NETS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
110	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1

APPENDIX 5. (continued)

Trout-perch Lake Michigan — SEINES

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
80	0	4	0	0	0	1	0	0	0	0	0	0	0	0	0	5
110	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
TOTALS	0	4	0	0	0	2	0	0	0	0	0	0	0	0	0	6

Trout-perch Lake Michigan — TRAWLS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	0	0	0	0	0	5	0	1	0	1	0	0	0	7
30	0	8	0	0	0	0	0	3	0	1	0	2	0	0	0	14
40	10	40	0	5	0	0	0	1	0	0	0	0	0	0	10	46
50	10	49	0	45	0	4	0	0	0	0	0	0	0	0	10	98
60	9	26	8	102	6	14	0	2	0	0	0	0	0	0	23	144
70	0	14	2	30	15	12	4	26	2	0	0	0	0	1	23	83
80	9	40	0	6	1	5	4	46	3	1	0	0	0	1	17	99
90	13	37	1	5	1	11	0	19	1	1	0	0	0	0	16	73
100	1	20	1	5	0	9	1	6	0	5	0	0	1	0	4	45
110	2	10	0	5	1	13	0	8	0	9	0	6	0	0	3	51
120	2	7	0	3	0	16	0	5	0	4	0	6	0	1	2	42
130	3	11	0	1	0	10	0	0	0	6	0	2	1	0	4	30
140	0	0	0	0	0	1	0	0	0	2	0	2	0	0	0	5
150	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	3
160	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTALS	59	263	12	207	24	95	9	121	6	30	0	22	2	3	112	741

Trout-perch Lake Michigan — BOTTOM GILL NETS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
100	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
110	0	0	0	0	0	3	1	1	0	0	0	4	0	0	1	8
120	0	0	0	2	0	2	0	1	0	0	0	11	0	0	0	16
130	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	4
140	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	3
150	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTALS	0	0	0	2	0	8	1	2	0	0	0	21	0	0	1	33

APPENDIX 5. (continued)

Yellow perch Lake Michigan

SEINES

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
30	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
40	0	0	1	3	0	0	1	0	0	0	0	0	0	0	2	3
50	0	0	0	0	0	0	33	0	0	0	0	1	0	0	33	1
60	0	0	0	1	0	0	183	1	0	0	0	1	0	0	183	3
70	0	0	0	0	0	0	39	0	0	0	0	0	0	0	39	0
80	0	0	0	0	0	0	13	0	0	0	0	0	0	0	13	0
90	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3	0
100	0	0	1	1	0	0	2	0	0	0	0	0	0	0	3	1
110	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3
120	0	0	1	5	0	1	0	0	0	0	0	0	0	0	1	6
130	0	0	0	1	0	5	0	0	0	0	0	0	0	0	0	6
140	0	0	0	1	0	2	2	0	0	0	0	0	0	0	2	3
150	0	0	0	1	0	2	1	0	0	0	0	0	0	0	1	3
160	0	0	0	2	0	0	2	0	0	0	0	0	0	0	2	2
180	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	1
190	0	0	0	3	0	1	2	0	0	0	0	0	0	0	2	4
200	0	0	0	2	0	0	1	0	0	0	0	0	0	0	1	2
210	0	0	0	2	0	3	0	0	0	0	0	0	0	0	0	5
230	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	1
TOTALS	0	0	4	27	0	14	284	1	0	0	0	2	0	0	288	44

Yellow perch Lake Michigan

TRAWLS

LENGTH INTERVAL(mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
30	0	0	0	0	5	2	0	0	0	0	0	0	0	0	5	2
40	0	0	0	0	37	10	0	0	0	1	0	1	0	1	37	13
50	0	0	0	0	6	1	0	0	0	0	0	0	5	2	11	3
60	0	0	0	0	4	0	3	3	1	0	0	0	7	17	15	20
70	0	0	0	0	0	0	2	1	0	2	0	2	11	6	13	11
80	0	3	0	0	0	0	1	0	0	0	0	0	0	1	1	4
90	2	4	0	0	0	0	0	0	0	0	0	0	2	0	4	4
140	1	0	0	0	0	0	1	1	0	0	0	0	0	0	2	1
150	0	2	0	0	0	0	1	0	0	0	0	0	0	1	1	3
160	1	3	0	0	0	0	0	1	0	1	0	0	0	0	1	5
170	0	5	0	0	0	0	0	1	0	1	0	0	0	0	0	7
180	1	4	0	1	0	0	3	0	0	0	0	0	0	0	4	5
190	1	1	0	2	0	0	4	1	0	0	0	0	0	0	5	4
200	0	1	0	0	0	0	2	0	0	0	0	0	0	0	2	1
210	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0
220	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	1
230	1	0	0	2	0	0	1	0	0	0	0	0	0	0	2	2
240	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	4
250	0	1	0	0	0	1	2	0	0	0	0	1	0	0	2	1
260	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
TOTALS	8	26	0	5	52	14	23	9	1	5	0	4	26	28	110	91

APPENDIX 5. (continued)

Yellow perch Lake Michigan

BOTTOM GILL NETS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
100	0	0	0	0	1	0	0	2	0	0	0	0	0	0	1	2
110	0	0	0	2	0	0	1	0	0	0	0	0	0	0	1	2
120	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
130	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
140	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1
150	3	0	0	0	3	1	6	3	0	0	1	1	0	0	13	5
160	26	0	5	0	3	2	10	4	0	0	0	4	0	0	44	10
170	15	0	7	5	9	5	5	2	0	0	0	3	0	0	36	15
180	5	0	3	5	67	7	5	3	0	0	0	1	0	0	80	16
190	1	0	6	10	38	9	16	5	0	0	0	1	0	0	61	25
200	2	0	7	8	36	7	17	5	0	0	1	6	0	0	63	26
210	2	0	3	2	56	6	19	5	0	0	1	2	0	0	81	15
220	0	0	5	2	20	8	8	6	0	0	1	5	0	0	34	21
230	0	0	6	6	6	4	1	4	0	0	0	5	0	0	13	19
240	0	0	8	2	23	7	5	1	0	0	0	4	0	0	36	14
250	0	0	4	2	6	3	2	2	0	0	0	1	0	0	12	8
260	1	0	3	4	9	3	2	0	0	0	0	0	0	0	15	7
270	1	0	0	0	11	2	1	0	0	0	0	0	0	0	13	2
280	0	0	3	0	8	2	3	0	1	0	0	0	0	0	15	2
290	0	0	1	0	4	0	2	0	0	0	0	0	0	0	7	0
310	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
320	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
330	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TOTALS	58	0	63	48	302	66	103	43	1	0	4	33	0	0	531	190

APPENDIX 5. (continued)

Alewife Pigeon Lake

SEINES

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	0	0	0	1	19	0	0	0	0	0	0	0	0	1	19
30	0	0	3312	0	0	155	77	27	0	0	0	0	0	0	3389	182
40	1	0	3330	0	0	0	4	19	1	0	0	0	0	0	3306	19
50	0	0	145	0	0	0	0	0	0	0	0	0	0	0	145	0
170	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
190	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TOTALS	3	0	6757	0	1	174	81	46	1	0	0	0	0	0	6843	220

Alewife Pigeon Lake

BOTTOM GILL NETS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
60	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
130	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
150	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
160	1	0	0	0	0	1	0	2	0	0	0	0	0	0	1	3
170	3	0	0	1	0	3	0	3	0	0	0	0	0	0	3	7
180	3	2	0	0	0	2	0	1	0	1	0	0	0	0	3	6
190	1	1	0	0	0	1	0	0	0	2	0	0	0	0	1	4
TOTALS	9	3	0	1	0	8	0	6	0	3	0	0	0	1	9	22

APPENDIX 5. (continued)

Bluntnose minnow Pigeon Lake

	SEINES															
LENGTH	JUN		JUL		AUG		SEP		OCT		NOV		DEC		SUM	
INTERVAL (mm)	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT	DAY	NGT
10	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
20	0	0	0	1	50	6	0	0	0	0	0	0	0	0	50	7
30	0	0	115	4	276	13	17	1	1	0	0	30	0	0	409	48
40	9	36	207	11	215	51	57	9	1	2	1	2	0	0	570	111
50	3	78	50	12	31	1	15	10	0	1	0	1	0	0	99	103
60	0	28	72	12	6	0	0	1	0	0	0	2	0	0	78	43
70	0	19	1	15	3	0	0	0	0	0	0	0	0	0	4	34
80	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	3
TOTALS	12	162	525	57	582	71	89	21	2	3	1	35	0	0	1211	349

APPENDIX 5. (continued)

Golden shiner Pigeon Lake SEINES

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
40	0	0	492	294	40	28	0	3	0	0	0	0	0	0	532	325
50	0	8	230	236	155	91	50	19	0	0	1	0	0	0	436	354
60	0	42	1	2	107	25	23	26	0	0	0	0	0	0	131	95
70	0	58	73	29	3	10	1	3	0	0	0	1	0	0	77	101
80	0	33	63	74	18	44	1	1	0	0	0	0	0	0	82	152
90	0	15	21	25	23	44	7	6	0	0	0	0	0	0	51	90
100	0	13	59	8	11	15	1	2	0	0	0	0	0	0	71	38
110	0	6	12	0	2	5	1	0	0	0	0	0	0	0	15	11
120	0	7	4	0	2	0	0	0	0	0	0	0	0	0	6	7
130	0	0	12	2	0	1	0	0	0	0	0	0	0	0	12	3
140	0	0	8	0	0	2	0	0	0	0	0	0	0	0	8	2
150	0	0	2	0	0	1	0	0	0	0	0	0	0	0	2	1
TOTALS	0	184	977	670	361	266	84	60	0	0	1	1	0	0	1423	1181

Golden shiner Pigeon Lake BOTTOM GILL NETS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
100	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
110	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	2
120	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
130	0	0	0	0	0	0	3	1	0	0	0	0	0	0	3	1
150	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
170	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
TOTALS	0	0	1	0	2	1	4	3	0	0	0	0	0	0	7	4

APPENDIX 5. (continued)

Largemouth bass Pigeon Lake

SEINES

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	157	43	0	0	0	0	0	0	0	0	0	0	0	0	157	43
30	52	17	1	0	0	0	0	0	0	0	0	0	0	0	53	17
40	0	0	4	3	2	1	0	0	0	0	0	0	0	0	6	4
50	0	0	36	35	4	4	0	0	1	0	0	0	0	0	41	39
60	0	0	23	31	24	28	4	1	0	0	6	0	0	0	57	60
70	0	0	22	7	16	19	9	16	3	4	11	0	0	0	61	46
80	0	0	5	3	9	10	38	12	0	4	10	2	0	0	62	31
90	0	1	0	1	7	3	13	3	3	0	10	3	0	0	33	11
100	1	0	0	0	1	2	4	0	0	0	3	2	0	0	9	4
110	1	0	0	0	0	1	3	0	0	0	1	2	0	0	5	3
120	0	0	0	2	0	0	0	0	0	0	1	1	0	0	1	3
130	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2	0
150	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
160	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
170	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2
370	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
550	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
TOTALS	211	62	91	83	63	70	72	32	8	8	44	10	0	0	489	265

Largemouth bass Pigeon Lake

BOTTOM GILL NETS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
100	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
210	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
330	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
350	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
370	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2	0
TOTALS	0	0	0	0	3	0	3	0	0	0	0	0	0	0	6	0

APPENDIX 5. (continued)

Spottail shiner Pigeon Lake

SEINES

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
10	0	0	0	0	4	0	0	0	0	0	0	0	0	0	4	0
20	0	0	12	25	130	41	0	0	1	2	0	0	0	0	143	68
30	0	0	435	47	185	80	355	474	43	18	0	0	0	0	1018	619
40	0	0	865	144	55	31	275	1077	39	12	3	1	0	0	1237	1265
50	0	2	13	7	0	1	42	104	0	0	4	1	0	0	59	115
60	0	1	4	1	0	0	0	5	0	0	0	0	0	0	4	7
70	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	3
110	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2
120	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
130	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
140	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	3	1329	228	374	153	672	1661	83	35	7	2	0	0	2465	2082

Spottail shiner Pigeon Lake

BOTTOM GILL NETS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
110	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2
120	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
130	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
140	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	0	0	0	3	0	0	0	0	0	2	0	0	0	0	0	5

APPENDIX 5. (continued)

Pumpkinseed Pigeon Lake

SEINES

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
30	0	0	1	0	1	0	0	1	1	3	1	1	0	0	4	5
40	0	1	4	0	8	6	1	8	4	8	0	2	0	0	17	25
50	0	3	1	0	6	4	0	4	2	4	11	9	0	0	20	24
60	1	3	0	1	0	2	1	1	4	4	11	4	0	0	17	15
70	1	2	0	3	0	4	1	0	0	1	0	0	0	0	2	10
80	0	0	5	3	0	3	0	0	0	0	0	0	0	0	5	6
90	0	1	4	1	1	3	0	0	1	0	0	0	0	0	6	5
100	2	2	0	1	1	0	3	0	1	0	0	0	0	0	7	3
110	0	1	0	0	1	5	0	1	0	0	0	0	0	0	1	7
120	2	2	1	5	1	2	0	0	2	2	3	0	0	0	9	11
130	0	1	0	3	0	0	1	0	0	0	0	0	0	0	1	4
140	0	1	0	2	0	2	0	1	1	0	0	1	0	0	1	7
150	0	0	1	1	0	2	0	0	0	0	0	0	0	0	1	3
160	0	3	0	1	1	1	0	0	0	0	0	0	0	0	1	5
170	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4
180	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
200	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	6	25	17	22	20	34	7	16	16	22	26	17	0	0	92	136

Pumpkinseed Pigeon Lake

BOTTOM GILL NETS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
140	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
150	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
160	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
170	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
TOTALS	0	0	0	0	0	0	2	0	0	0	2	0	0	0	4	0

APPENDIX 5. (continued)

Yellow perch Pigeon Lake

SEINES

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
20	12	5	0	0	0	0	0	0	0	0	0	0	0	0	12	5
30	51	14	0	0	0	0	0	0	0	0	0	0	0	0	51	14
40	0	0	24	13	0	0	0	0	2	0	1	0	0	0	27	13
50	0	0	93	175	2	8	0	1	0	0	0	0	0	0	95	184
60	0	0	104	312	65	77	1	11	0	11	1	10	0	0	171	421
70	0	0	6	74	30	81	12	38	7	10	2	13	0	0	57	216
80	0	0	0	1	16	9	83	54	15	7	6	15	0	0	120	86
90	0	1	0	0	0	0	35	16	13	16	4	9	0	0	52	42
100	0	0	0	0	0	0	1	1	5	1	6	1	0	0	12	3
110	0	1	0	1	0	0	0	2	1	0	3	0	0	0	4	4
120	0	2	3	4	0	1	0	0	1	1	0	0	0	0	4	8
130	10	14	4	0	0	5	1	0	1	2	5	1	0	0	21	22
140	28	50	7	9	1	2	3	0	2	2	11	1	0	0	52	64
150	9	32	7	23	3	10	9	1	6	2	6	5	0	0	40	73
160	18	35	3	19	6	4	19	2	3	0	8	7	0	0	57	67
170	2	11	3	16	8	9	5	2	3	3	15	3	0	0	36	44
180	4	6	7	11	4	13	21	5	5	4	14	3	0	0	55	42
190	0	0	0	7	1	3	14	5	3	1	25	3	0	0	43	19
200	1	0	0	0	0	3	10	3	4	1	9	4	0	0	24	11
210	0	0	0	1	1	1	3	3	2	1	5	1	0	0	11	7
220	0	0	0	0	0	0	2	2	1	0	6	2	0	0	9	4
230	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
240	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
250	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1
260	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
270	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
TOTALS	135	172	261	667	137	226	220	146	74	63	128	79	0	0	955	1353

Yellow perch Pigeon Lake

BOTTOM GILL NETS

LENGTH INTERVAL (mm)	JUN DAY	JUN NGT	JUL DAY	JUL NGT	AUG DAY	AUG NGT	SEP DAY	SEP NGT	OCT DAY	OCT NGT	NOV DAY	NOV NGT	DEC DAY	DEC NGT	SUM DAY	SUM NGT
100	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2	0
110	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
120	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
130	0	2	0	0	1	0	0	0	0	0	0	0	0	0	1	2
140	11	1	1	0	1	0	0	1	0	0	0	1	0	0	13	3
150	17	0	1	3	7	0	1	0	1	0	1	2	0	0	28	5
160	4	1	0	1	8	1	7	3	1	0	3	1	0	0	23	7
170	3	0	1	0	2	0	0	0	1	1	3	0	0	0	10	1
180	3	1	2	1	7	0	4	1	0	3	1	0	0	0	17	6
190	2	1	1	0	5	0	1	0	1	0	2	1	0	1	12	3
200	0	0	0	0	3	0	2	0	1	0	0	0	1	0	7	0
210	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
220	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
240	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
250	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
260	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
320	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
340	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TOTALS	44	6	7	6	34	1	16	5	5	4	12	5	4	2	122	29

APPENDIX 6

APPENDIX 6. Number of fish larvae and eggs per 1000 m^3 for south transect stations in Lake Michigan (Figure 1) near the J. H. Campbell Plant, eastern Lake Michigan, 31 May-December 1977. See Table 57 for definition of species codes. D = day, N = night.

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
6-03-77	D	A	0	9.0																								0	0
6-04-77	N	A	0	9.0																								0	0
6-03-77	D	B	0	9.0																								0	0
6-03-77	D	B	2	9.0																								0	0
6-04-77	N	B	0	7.0																								0	0
6-04-77	N	B	2	7.0																								0	0
6-03-77	D	C	0	9.5																								0	0
6-03-77	D	C	2	5.9																								0	0
6-03-77	D	C	4	5.9																								0	0
6-03-77	D	C	6	6.5																								0	0
6-01-77	N	C	0	10.0																								0	0
6-01-77	N	C	2	10.5										31														31	0
6-01-77	N	C	4	10.5																								0	211
6-01-77	N	C	6	11.2																								0	0
6-03-77	D	D	0	10.0																								0	0
6-03-77	D	D	2	6.8																								0	0
6-03-77	D	D	4	6.8																								0	0
6-03-77	D	D	6	10.0																								0	0
6-03-77	D	D	8	5.8																								0	0
6-01-77	N	D	0	11.3																								0	0
6-01-77	N	D	2	10.0																								0	0
6-01-77	N	D	4	10.0																								0	0
6-01-77	N	D	6	10.5																								0	0
6-01-77	N	D	8	9.2																								0	115
6-03-77	D	E	0	10.2																								0	0
6-03-77	D	E	3	10.2																								0	0
6-03-77	D	E	6	5.8																								0	0
6-03-77	D	E	9	5.8																								0	0
6-03-77	D	E	11	5.9																								0	0
5-31-77	N	E	0	10.5																								0	0
5-31-77	N	E	3	9.0																								0	72
5-31-77	N	E	6	9.0																								0	0
5-31-77	N	E	9	9.0																								0	0
5-31-77	N	E	11	12.0																								0	0
6-03-77	D	F	0	9.0																								0	0
6-03-77	D	F	4	6.6																								0	0
6-03-77	D	F	8	6.6																								0	0

APPENDIX 6. (continued)

					NUMBER OF LARVAE PER 1000 M^3																								
DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
6-03-77	D	F	12	12.5																								0	0
6-03-77	D	F	14	5.6																								0	0
5-31-77	N	F	0	11.0																								0	0
5-31-77	N	F	4	10.2																								0	0
5-31-77	N	F	9	10.2																								0	0
5-31-77	N	F	12	10.2																								0	0
5-31-77	N	F	14	5.5																								0	0
6-03-77	D	G	0	8.6																								0	0
6-03-77	D	G	4	8.6																								0	0
6-03-77	D	G	9	8.6																								0	0
6-03-77	D	G	14	5.1																								0	0
6-03-77	D	G	17	18.0																								0	0
5-31-77	N	G	0	11.8																								0	0
5-31-77	N	G	4	11.8																								0	0
5-31-77	N	G	9	11.8																								0	0
5-31-77	N	G	14	11.8																								0	0
5-31-77	N	G	17	5.0																								0	0
6-03-77	D	H	0	8.5																								0	0
6-03-77	D	H	5	5.0																								0	0
6-03-77	D	H	10	5.0																								0	0
6-03-77	D	H	15	5.0																								0	0
6-03-77	D	H	20	5.0																								0	0
5-31-77	N	H	0	11.9																								0	0
5-31-77	N	H	5	4.8																								0	0
5-31-77	N	H	10	4.8																								0	0
5-31-77	N	H	15	4.8																								0	0
5-31-77	N	H	20	4.4																								0	0
6-03-77	D	P	0	13.0																								0	0
6-03-77	D	P	0	13.0																								0	0
6-04-77	N	P	0	9.5																								0	146
6-04-77	N	P	0	9.5																								0	0

APPENDIX 6. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
6-22-77	D	A	0	16.0																								0	0
6-22-77	N	A	0	16.0																								0	0
6-22-77	D	B	0	16.0																								0	0
6-22-77	D	B	2	15.4																								0	0
6-22-77	N	B	0	16.6			88																					88	0
6-22-77	N	B	2	15.8		90																						90	0
6-18-77	D	C	0	16.5																								0	0
6-18-77	D	C	2	15.5																								0	0
6-18-77	D	C	4	15.5																								0	0
6-13-77	D	C	6	16.5			19																					19	0
6-17-77	N	C	0	13.5			62																					62	0
6-17-77	N	C	2	13.5			334																					334	0
6-17-77	N	C	4	13.5			53																					53	0
6-17-77	N	C	6	13.0			19																					19	0
6-18-77	D	D	0	16.5																								0	0
6-18-77	D	D	2	15.5																								0	0
6-18-77	D	D	4	15.5			22																					22	0
6-18-77	D	D	6	15.5			64																					64	0
6-18-77	D	D	8	15.5			21																					21	0
6-17-77	N	D	0	13.5																								0	0
6-17-77	N	D	2	13.0			244																					244	0
6-17-77	N	D	4	13.0			52																					52	0
6-17-77	N	D	6	13.0											22													22	0
6-17-77	N	D	8	12.5																								0	0
6-18-77	D	E	0	14.8																								0	0
6-18-77	D	E	3	14.5																								0	155
6-18-77	D	E	6	14.5	20		163																					183	0
6-18-77	D	E	9	14.5			64																					64	0
6-18-77	D	E	11	14.5			50																					50	0
6-17-77	N	E	0	14.3			32																					32	0
6-17-77	N	E	3	12.9							20																	20	0
6-17-77	N	E	6	12.9			18																					18	0
6-17-77	N	E	9	12.9	24		24																					48	0
6-17-77	N	E	11	10.9																								0	0
6-18-77	D	F	0	14.0																								0	0
6-18-77	D	F	4	13.5			21																		21				42	0
6-18-77	D	F	8	13.5	36		109																					145	0
6-18-77	D	F	12	13.0	23																							23	0

APPENDIX 6. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
6-18-77	D	F	14	13.0																								0	0
6-18-77	N	F	0	13.5			43					14																57	0
6-18-77	N	F	4	11.5																								0	0
6-18-77	N	F	8	11.5																								0	0
6-18-77	N	F	12	11.5																								0	0
6-18-77	N	F	14	8.5																								0	0
6-18-77	D	G	0	12.5																								0	0
6-18-77	D	G	4	11.5																								0	0
6-18-77	D	G	9	11.5								141																141	0
6-18-77	D	G	14	11.5	97							95																192	0
6-18-77	D	G	17	11.5																								0	0
6-18-77	N	G	0	13.0								16																16	0
6-18-77	N	G	4	11.0	18																							18	0
6-18-77	N	G	9	11.0																								0	0
6-18-77	N	G	14	8.0																								0	0
6-18-77	N	G	17	8.0																								0	0
6-18-77	D	H	0	12.0																								0	0
6-18-77	D	H	5	11.0	44																							44	0
6-18-77	D	H	10	11.0								93																93	0
6-18-77	D	H	15	11.0																								0	0
6-18-77	D	H	20	10.0																								0	0
6-17-77	N	H	0	13.0			22					88																110	0
6-18-77	N	H	5	9.5	15																							15	0
6-18-77	N	H	10	9.5																								0	0
6-18-77	N	H	15	9.5	46																							46	0
6-18-77	N	H	20	7.0																								0	0
6-22-77	D	P	0	17.5																								0	1515
6-22-77	D	P	0	17.5																								0	0
6-22-77	N	P	0	16.0																								0	0
6-22-77	N	P	0	16.0																								0	0

APPENDIX 6. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PE	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
7-08-77	D	A	0	22.5	1068																							1068	0
7-07-77	N	A	0	21.5	2786	3525									79													6390	132
7-08-77	D	B	0	21.5	367																							367	0
7-08-77	D	B	2	21.5	14535	24																						14559	0
7-07-77	N	B	0	21.5	180	40			21						185													426	0
7-07-77	N	B	2	20.4	2677	23			70																			2760	0
7-09-77	D	C	0	22.0	532																							532	0
7-09-77	D	C	2	22.0	815																							815	0
7-09-77	D	C	4	22.0	732																							732	0
7-09-77	D	C	6	22.0	1718		38																					1756	0
7-09-77	N	C	0	19.0	422																							422	0
7-09-77	N	C	2	16.0	690																							690	0
7-09-77	N	C	4	16.0	6007	24																						6031	0
7-09-77	N	C	6	14.0	3724				364																			4088	0
7-09-77	D	D	0	22.0	481																							481	0
7-09-77	D	D	2	20.0	3619																							3619	0
7-09-77	D	D	4	20.0	1210																							1210	0
7-09-77	D	D	6	20.0	4860																							4860	0
7-09-77	D	D	8	18.0	7803																							7803	51
7-09-77	N	D	0	18.0	2971	30																						3001	0
7-09-77	N	D	2	15.0	4614																							4614	0
7-09-77	N	D	4	15.0	6298				26																			6324	0
7-09-77	N	D	6	15.0	5394				26				26															5446	26
7-09-77	N	D	8	14.0	2561				40																			2601	0
6-09-77	D	E	0	22.0	109																							109	0
7-07-77	D	E	3	20.0	1164																							1164	0
7-07-77	D	E	6	20.0	1471																							1461	0
7-07-77	D	E	9	20.0	372																							372	0
7-07-77	D	E	11	15.0	1221																							1221	0
7-09-77	N	E	0	19.0	4306								40															4346	0
7-09-77	N	E	3	16.0	7906	25																						7731	0
7-09-77	N	E	6	16.0	554	25									181													760	0
7-09-77	N	E	9	16.0	4597		17		34																			4648	0
7-09-77	N	E	11	12.0	499				69																			568	0
7-09-77	D	F	0	22.0	192																							192	0
7-09-77	D	F	4	21.0	2719																							2719	0
7-09-77	D	F	8	21.0	1353																							1353	0

APPENDIX 6. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
7-09-77	D	F	12	21.0	236																							236	0
7-09-77	D	F	14	16.0	3612																							3612	0
7-09-77	N	F	0	18.0	2692																							2692	0
7-09-77	N	F	4	15.0	3741																							3741	0
7-09-77	N	F	8	15.0																								0	0
7-09-77	N	F	12	15.0	109																							109	0
7-09-77	N	F	14	12.0	70																							70	0
7-07-77	D	G	0	21.0	536																							536	0
7-07-77	D	G	4	19.0	4350																							4350	0
7-07-77	D	G	9	19.0	60																							60	0
7-07-77	D	G	14	19.0	304																							304	0
7-07-77	D	G	17	16.0	0																							0	0
7-09-77	N	G	0	18.0	854										184													1038	0
7-09-77	N	G	4	14.0	1019								18															1037	0
7-09-77	N	G	9	14.0	353	23																						376	0
7-09-77	N	G	14	14.0	42																							42	0
7-10-77	N	G	17	9.0																								0	0
7-09-77	D	H	0	22.0	657																							657	0
7-09-77	D	H	5	20.0	4767																							4767	0
7-09-77	D	H	10	20.0	1185																							1185	0
7-09-77	D	H	15	20.0	213																							213	0
7-09-77	D	H	20	14.0	246																							246	0
7-10-77	N	H	0	18.0	1246		17																					1264	0
7-10-77	N	H	5	16.0	2430																							2430	0
7-10-77	N	H	10	16.0	217																							217	0
7-10-77	N	H	15	16.0	56										27													83	0
7-10-77	N	H	20	11.0	43																							43	0
7-08-77	D	P	0	24.5	716				408																			1124	0
7-08-77	D	P	0	24.5	285				952																			1237	0
7-07-77	N	P	0	20.4	1089	3269																						4358	0
7-07-77	N	P	0	20.4	2665	3895																						6560	0

APPENDIX 6. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
7-28-77	D	A	0	11.0	53																							53	0
7-28-77	N	A	0	13.0	64				64																64			192	0
7-28-77	D	B	0	11.0																								0	0
7-28-77	D	B	2	10.8	444	822																						1266	0
7-28-77	N	B	0	13.0	22																							22	0
7-28-77	N	B	2	11.2	399																							399	0
7-27-77	D	C	0	9.2	50																							50	0
7-27-77	D	C	2	7.2	31																							31	0
7-27-77	D	C	4	7.2																								0	0
7-27-77	D	C	6	7.4	19																							19	0
7-28-77	N	C	0	13.0																								0	0
7-28-77	N	C	2	12.0																								0	0
7-28-77	N	C	4	12.0																								0	0
7-28-77	N	C	6	10.4		47																						47	0
7-27-77	D	D	0	9.0	184																							184	0
7-27-77	D	D	2	5.2																								0	0
7-27-77	D	D	4	5.2																								0	0
7-27-77	D	D	6	9.0																								0	0
7-27-77	D	D	8	5.2																								0	0
7-27-77	N	D	0	10.0	28																							28	0
7-27-77	N	D	2	5.0	21																							21	0
7-27-77	N	D	4	5.0	52																							52	0
7-27-77	N	D	6	5.0																								0	0
7-27-77	N	D	8	4.0																								0	0
7-27-77	D	E	0	10.3																								0	0
7-27-77	D	E	3	5.0																								0	0
7-27-77	D	E	6	5.0																								0	0
7-27-77	D	E	9	5.0																								0	0
7-27-77	D	E	11	5.4																								0	0
7-27-77	N	E	0	11.0	95																							95	0
7-27-77	N	E	3	7.3	87																							87	0
7-27-77	N	E	6	7.3	19																							19	0
7-27-77	N	E	9	7.3																								0	0
7-27-77	N	E	11	5.0																								0	0
7-27-77	D	F	0	11.7																								0	0
7-27-77	D	F	4	4.8	25																							25	0
7-27-77.	D	F	8	4.8																								0	0
7-27-77	D	F	12	4.8	20																							20	0

APPENDIX 6. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
7-27-77	D	F	14	4.8																			17					17	0
7-27-77	N	F	0	12.2	60																							60	0
7-27-77	N	F	4	4.2	40																							40	0
7-27-77	N	F	8	4.2	46																							46	0
7-27-77	N	F	12	4.2	17																							17	0
7-27-77	N	F	14	4.3																								0	0
7-27-77	D	G	0	11.0																								0	0
7-27-77	D	G	4	4.4	106																							106	0
7-27-77	D	G	9	4.4	56																							56	0
7-27-77	D	G	14	4.4																								0	0
7-27-77	D	G	17	4.4																								0	0
7-27-77	N	G	0	11.8	91																							91	0
7-27-77	N	G	4	5.5	54																							54	0
7-27-77	N	G	9	5.5																								0	0
7-27-77	N	G	14	5.5	48																							48	0
7-27-77	N	G	17	4.0	51																							51	0
7-27-77	D	H	0	11.8																								0	0
7-27-77	D	H	5	4.1	40																							40	0
7-27-77	D	H	10	4.1	38																							38	0
7-27-77	D	H	15	4.1																			13					13	0
7-27-77	D	H	20	4.1	16																							16	0
7-27-77	N	H	0	12.0																								0	0
7-27-77	N	H	5	6.5	95																							95	0
7-27-77	N	H	10	6.5																			20					20	0
7-27-77	N	H	15	6.5																								0	0
7-27-77	N	H	20	4.0																								0	0
7-26-77	D	P	0	16.0	1446				870																			2316	10435
7-26-77	D	P	0	15.5	2201																							2201	0
7-25-77	N	P	0	16.0	5357	324			1956																			7637	0
7-25-77	N	P	0	16.0	5669				6390																			12059	0

APPENDIX 6. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
8-15-77	D	A	0	22.9																								0	0
8-15-77	N	A	0	20.0	22																							22	0
8-15-77	D	B	0	22.6																								0	0
8-15-77	D	B	2	22.6	220																							220	0
8-16-77	N	B	0	20.0	160																							160	0
8-16-77	N	B	2	19.4	14																							14	0
8-18-77	D	C	0	17.2																								0	0
8-18-77	D	C	2	15.8	237																							237	0
8-18-77	D	C	4	15.8																								0	0
8-18-77	D	C	6	8.9																								0	0
8-18-77	N	C	0	17.0	320																							320	0
8-18-77	N	C	2	12.0	80																							80	0
8-18-77	N	C	4	12.0																								0	0
8-18-77	N	C	6	5.0																								0	0
8-18-77	D	D	0	18.5	23																							23	0
8-18-77	D	D	2	15.7	58																							58	0
8-18-77	D	D	4	15.7																								0	0
8-18-77	D	D	6	15.7	108																							108	0
8-18-77	D	D	8	6.0	39																							39	0
8-18-77	N	D	0	15.1	270																							270	0
8-18-77	N	D	2	12.2																								0	0
8-18-77	N	D	4	12.2	18																							18	0
8-18-77	N	D	6	12.2																								0	0
8-18-77	N	D	8	5.0																								0	0
8-18-77	D	E	0	18.2	72																							72	0
8-18-77	D	E	3	14.0	81																							81	0
8-18-77	D	E	6	14.0																								0	0
8-18-77	D	E	9	14.0																								0	0
8-18-77	D	E	11	5.0	39																							39	0
8-18-77	N	E	0	15.9	171																							171	0
8-18-77	N	E	3	12.2	144																							144	0
8-18-77	N	E	6	12.2	19																							19	0
8-18-77	N	E	9	12.2																								0	0
8-18-77	N	E	11	4.6																								0	0
8-18-77	D	F	0	20.1																								0	0
8-18-77	D	F	4	5.1	220																							220	0
8-18-77	D	F	8	5.1																								0	0
8-18-77	D	F	12	5.1																								0	0

APPENDIX 6. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
8-18-77	D	F	14	4.8																								0	0
8-18-77	N	F	0	16.5	308																							308	0
8-18-77	N	F	4	6.0	134																							134	0
8-18-77	N	F	8	6.0	60																							60	0
8-18-77	N	F	12	6.0																								0	0
8-18-77	N	F	14	4.8	20																							20	0
8-18-77	D	G	0	17.6																								0	0
8-18-77	D	G	4	13.8	44																							44	0
8-18-77	D	G	8	13.8																								0	0
8-18-77	D	G	14	13.8	26																							26	0
8-18-77	D	G	17	4.8																								0	0
8-18-77	N	G	0	18.0	308																							308	0
8-18-77	N	G	4	15.1	242																							242	0
8-18-77	N	G	9	15.1																								0	0
8-18-77	N	G	14	15.1																							FS:19	19	0
8-18-77	N	G	17	4.7																							FS:14	14	0
8-18-77	D	H	0	19.8																								0	0
8-18-77	D	H	5	7.8	54																							54	0
8-18-77	D	H	10	7.8																								0	0
8-18-77	D	H	15	7.8																								0	0
8-18-77	D	H	20	4.7																								0	0
8-18-77	N	H	0	18.0																								0	0
8-18-77	N	H	5	14.9																								0	0
8-18-77	N	H	10	14.9																								0	0
8-18-77	N	H	15	14.9	18																							18	0
8-18-77	N	H	20	4.2																								0	0
8-15-77	D	P	0	24.7																								0	0
8-15-77	D	P	0	24.7	146																							146	0
8-16-77	N	P	0	21.5																								0	0
8-16-77	N	P	0	21.5	120																							120	0

APPENDIX 6. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
9-22-77	D	A	0	12.5	361																							361	0
9-22-77	N	A	0	12.5																								0	0
9-22-77	D	B	0	12.5	100																							100	0
9-22-77	D	B	2	12.5	250																							250	0
9-22-77	N	B	0	12.5																								0	0
9-22-77	N	B	2	12.5	27																							27	0
9-22-77	D	C	0	12.7	19																							19	0
9-22-77	D	C	2	11.7																								0	0
9-22-77	D	C	4	11.7																								0	0
9-22-77	D	C	6	11.7																								0	0
9-22-77	N	C	0	12.8																								0	0
9-22-77	N	C	2	12.3	17																							17	0
9-22-77	N	C	4	12.3																								0	0
9-22-77	N	C	6	12.3	30																							30	0
9-22-77	D	D	0	13.2																								0	0
9-22-77	D	D	2	9.9																								0	0
9-22-77	D	D	4	9.9																								0	0
9-22-77	D	D	6	9.9	16																							16	0
9-22-77	D	D	8	9.9																								0	0
9-22-77	N	D	0	12.8	38																							38	0
9-22-77	N	D	2	11.5																								0	0
9-22-77	N	D	4	11.5	18																							18	0
9-22-77	N	D	6	11.5																								0	0
9-22-77	N	D	8	10.7	30																							30	0
9-22-77	D	E	0	13.5																								0	0
9-22-77	D	E	3	9.5																								0	0
9-22-77	D	E	6	9.5																								0	0
9-22-77	D	E	9	9.5																								0	0
9-22-77	D	E	11	8.2																								0	0
9-22-77	N	E	0	12.5	19																							19	0
9-22-77	N	E	3	9.3																								0	0
9-22-77	N	E	6	9.3																								0	0
9-22-77	N	E	9	9.3																								0	0
9-22-77	N	E	11	8.0																								0	0
9-22-77	D	F	0	15.0																								0	0
9-22-77	D	F	4	6.6																								0	0
9-22-77	D	F	8	6.6																								0	0
9-22-77	D	F	12	6.6																								0	0

APPENDIX 6. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	NUMBER OF LARVAE PER 1000 M^3																							TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.		
9-22-77	D	F	14	7.0																								0	0
9-22-77	N	F	0	12.5																								0	0
9-22-77	N	F	4	8.3																								0	0
9-22-77	N	F	8	8.3	14																							14	0
9-22-77	N	F	12	8.3																								0	0
9-22-77	N	F	14	7.5																								0	0
9-22-77	D	G	0	15.0																								0	0
9-22-77	D	G	4	6.5																								0	0
9-22-77	D	G	9	6.5																								0	0
9-22-77	D	G	14	6.5																								0	0
9-22-77	D	G	17	6.5																								0	0
9-22-77	D	H	0	15.7																								0	0
9-22-77	D	H	5	9.3																								0	0
9-22-77	D	H	10	9.3																								0	0
9-22-77	D	H	15	9.3																								0	0
9-22-77	D	H	20	5.3																								0	0
9-21-77	D	P	0	11.1																								0	0
9-21-77	D	P	0	11.1	310																							310	0
9-22-77	N	P	0	12.5																								0	0
9-22-77	N	P	0	12.5																								0	0
10-20-77	D	P	0	11.3																								0	0
10-20-77	D	P	0	11.3																								0	0
10-19-77	N	P	0	10.5																								0	0
10-19-77	N	P	0	10.5																								0	0
10-31-77	D	P	0	11.3																								0	0
10-31-77	D	P	0	11.3																								0	0
11-2-77	N	P	0	12.1																								0	0
11-2-77	N	P	0	12.1																								0	0

APPENDIX 7

APPENDIX 7. Number of fish larvae and eggs per 1000 m^3 for north transect stations in Lake Michigan (Figure 1) near the J. H. Campbell Plant June - December 1977. See Table 57 for definition of species codes. D = day, N = night.

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
6-03-77	D	L	0	12.0																								0	0
6-03-77	D	L	2	6.3																								0	0
6-03-77	D	L	4	6.3																								0	0
6-03-77	D	L	6	6.3																								0	0
6-03-77	N	L	0	10.5											79													79	306
6-03-77	N	L	2	10.0																								0	0
6-03-77	N	L	4	10.0																								0	55
6-03-77	N	L	6	10.0																								0	0
6-03-77	D	R	0	12.0	146																							146	0
6-03-77	D	R	0	12.0																								0	0
6-03-77	N	R	0	10.6		292																						292	0
6-03-77	N	R	0	10.6					292																			292	877
6-03-77	D	Q	0	17.0																								0	0
6-03-77	D	Q	0	17.0					146																			146	0
6-03-77	N	Q	0	8.0																								0	0
6-03-77	N	Q	0	8.0																								0	0
6-18-77	D	L	0	16.0																								0	0
6-18-77	D	L	2	15.5	21		21																					42	0
6-18-77	D	L	4	15.5			19																					19	38
6-18-77	D	L	6	15.5																								0	0
6-17-77	N	L	0	16.5																								0	0
6-17-77	N	L	2	14.5					21																			21	0
6-17-77	N	L	4	14.5					20																			20	285
6-17-77	N	L	6	12.5																								0	0
6-22-77	D	Q	0	19.6																								0	321
6-22-77	D	Q	0	19.6																								0	355
6-22-77	N	Q	0	16.0																								0	0
6-22-77	N	Q	0	16.0					292																			292	0
6-22-77	D	R	0	19.6																								0	0
6-22-77	D	R	0	19.6																								0	1969
6-22-77	N	R	0	16.0																								0	0
6-22-77	N	R	0	16.0					342																			342	0

APPENDIX 7. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
7-09-77	D	L	0	21.0	342																							342	0
7-09-77	D	L	2	21.0	365																							365	0
7-09-77	D	L	4	21.0	195								32															227	0
7-09-77	D	L	6	21.0	54	18																						72	0
7-09-77	N	L	0	21.0	2176																							2176	17
7-09-77	N	L	2	21.0	999																							999	0
7-09-77	N	L	4	19.0	1585																							1585	0
7-09-77	N	L	6	17.0	969																							969	17
7-07-77	D	Q	0	31.5	5370																							5370	1478
7-07-77	D	Q	0	31.5	932																							932	0
7-07-77	N	Q	0	31.5	1553	97			1264																		XL:97	3011	0
7-07-77	N	Q	0	31.5	1717	814																						2531	0
7-07-77	D	R	0	24.2	2020	5050																						7070	0
7-07-77	D	R	0	24.2	1649				6410																			8059	1034
7-07-77	N	R	0	24.2																									
					10021				7562						138													17721	137
7-07-77	N	R	0	24.2	7671																								
						10490							591		296													19048	0
7-13-77	D	I	0	29.0	1200																							1200	0
7-13-77	N	I	0	29.0	4396		39		213						39													4687	78
7-13-77	D	J	0	24.0	2193										56													2249	0
7-13-77	D	J	2	18.5	1441																							1441	0
7-13-77	N	J	0	--	429	165																						594	0
7-13-77	N	J	2	7.0	221	140			20																			381	0
7-13-77	D	L	0	22.8	996																							996	0
7-13-77	D	L	3	18.8	319																							319	0
7-13-77	D	L	6	17.0	603																							603	0
7-13-77	N	L	0	18.5	3364	23																						3387	0
7-13-77	N	L	3	18.0	984																							984	0
7-13-77	N	L	6	17.0	185																							185	109

APPENDIX 7. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	NUMBER OF LARVAE PER 1000 M^3 AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
7-13-77	D	N	0	23.3	361																							361	0
7-13-77	D	N	4	17.3	561																							561	0
7-13-77	D	N	8	16.2	311										22													333	0
7-13-77	N	N	0	23.3	4491																							4491	0
7-13-77	N	N	4	--	954	66																						1020	0
7-13-77	N	N	8	28.2	282																							282	0
7-13-77	D	O	0	21.5	5381																							5381	0
7-13-77	D	O	6	16.7	589	19																						608	76
7-13-77	D	O	8	16.0	355																							355	0
7-13-77	N	O	0	--	2069	19																						2088	0
7-13-77	N	O	6	20.0	2511										25													2536	0
7-13-77	N	O	8	16.0	1788																							1788	0
7-13-77	D	R	0	29.0	2002																							2002	0
7-13-77	D	R	0	29.0	3728																							3728	0
7-13-77	N	R	0	29.0	6945	1128																						8073	0
7-13-77	N	R	0	29.0	5422	570																						5992	0

APPENDIX 7. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
7-28-77	D	I	0	11.8									38															38	2077
7-28-77	N	I	0	11.4	39																							39	40
7-28-77	D	J	0	12.0																								0	163
7-28-77	D	J	2	11.6																								0	943
7-28-77	N	J	0	11.8	72																							72	0
7-28-77	N	J	2	11.8	124																							124	0
7-28-77	D	L	0	12.6																								0	0
7-28-77	D	L	2	12.6																								0	0
7-28-77	D	L	4	12.0																								0	0
7-28-77	D	L	6	10.2	94																							94	0
7-28-77	N	L	0	11.7	80																							80	0
7-28-77	N	L	2	10.7	44																							44	0
7-28-77	N	L	4	10.7	48																							48	0
7-28-77	N	L	6	9.0																								0	0
7-28-77	D	N	0	13.0	20																							20	0
7-28077	D	N	2	12.0	90																							90	0
7-28-77	D	N	4	12.0	57																							57	0
7-28-77	D	N	6	12.0	89																							89	0
7-28-77	D	N	8	9.8	39	39																						78	0
7-28-77	N	N	0	12.6	280																							280	0
7-28-77	N	N	2	11.3	514																							514	0
7-28-77	N	N	4	11.3	264																							264	0
7-28-77	N	N	6	11.3	27																							27	0
7-28-77	N	N	8	8.2	104																							104	0
7-28-77	D	O	0	12.6																								0	0
7-28-77	D	O	3	10.4	108																							108	0
7-28-77	D	O	6	10.4	0																							0	0
7-28-77	D	O	9	10.4	37																							37	0
7-28-77	D	O	11	7.3	0																							0	0
7-28-77	N	O	0	12.0	280																							280	0
7-28-77	N	O	3	7.1	558																							558	0
7-28-77	N	O	6	7.1	159								103															262	0
7-28-77	N	O	9	7.1	102																							102	0
7-28-77	N	O	11	6.0	64																							64	0

APPENDIX 7. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	NUMBER OF LARVAE PER 1000 M^3 AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
7-26-77	D	Q	0	22.0	216																							216	103623
7-26-77	D	Q	0	22.0	370																							370	34970
7-25-77	N	Q	0	20.0	6090	6464			12954						2286													27794	190
7-25-77	N	Q	0	20.0	984	1970			8395																			11349	0
7-26-77	D	R	0	15.7	292										146													438	804094
7-26-77	D	R	0	15.7	146																							146	219298
7-25-77	N	R	0	17.0	459				766																			1225	0
7-25-77	N	R	0	17.0	1192	1702			2222																			5116	0

APPENDIX 7. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
8-15-77	D	I	0	24.3	27										27													54	0
8-16-77	N	I	0	21.4																								0	0
8-15-77	D	J	0	22.3	58																							58	0
8-15-77	D	J	2	21.9	256																							256	0
8-16-77	N	J	0	21.4	143																							143	0
8-16-77	N	J	2	20.9	58																							58	0
8-19-77	D	L	0	17.0	57																							57	0
8-19-77	D	L	2	15.2	221																							221	0
8-19-77	D	L	4	15.2	46																							46	0
8-19-77	D	L	6	7.0																								0	0
8-18-77	N	L	0	13.1	663																							663	0
8-18-77	N	L	2	8.5	1162																							1162	0
8-18-77	N	L	4	8.5																								0	0
8-18-77	N	L	6	5.2	19																							19	0
8-19-77	D	N	0	15.3																								0	0
8-19-77	D	N	2	13.2	63																							63	0
8-19-77	D	N	4	13.2																								0	0
8-19-77	D	N	6	13.2	23																							23	0
8-19-77	D	N	8	6.0																								0	0
8-18-77	N	N	0	14.5	394																							394	0
8-18-77	N	N	2	6.0	775																							775	0
8-18-77	N	N	4	6.0	56																							56	0
8-18-77	N	N	6	6.0	36																							36	0
8-18-77	N	N	8	5.1	36																							36	0
8-19-77	D	O	0	16.0																								0	0
8-19-77	D	O	3	10.0	95																							95	0
8-19-77	D	O	6	10.0	108																							108	0
8-19-77	D	O	9	10.0																								0	0
8-19-77	D	O	11	5.2	25																							25	0
8-18-77	N	O	0	16.2	218																							218	0
8-18-77	N	O	3	15.0	126																							126	0
8-18-77	N	O	6	15.0	76																							76	0
8-18-77	N	O	9	15.0	16																							16	0
8-18-77	N	O	11	5.5																								0	0

APPENDIX 7. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	NUMBER OF LARVAE PER 1000 M^3 AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
8-15-77	D	Q	0	25.0	126																							126	0
8-15-77	D	Q	0	25.0	146				146																			292	0
8-16-77	N	Q	0	20.6	134																							134	0
8-16=77	N	Q	0	20.6	0																							0	0
8-15-77	D	R	0	24.4	1494																							1494	0
8-15-77	D	R	0	24.4	1168																							1168	0
8-16-77	N	R	0	21.5	146																							146	0
8-16-77	N	R	0	21.5	156																							156	0

APPENDIX 7. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
9-22-77	D	I	0	10.1	13																							13	0
9-23-77	N	I	0	10.1	26																							26	0
9-22-77	D	J	0	10.1	14																							14	0
9-22-77	D	J	2	9.3																								0	0
9-22-77	N	J	0	10.1																								0	0
9-23-77	N	J	2	9.3	27																							27	0
9-22-77	D	L	0	10.9																								0	0
9-22-77	D	L	2	10.1																								0	0
9-22-77	D	L	4	10.1																								0	0
9-22-77	D	L	6	10.1																								0	0
9-22-77	N	L	0	12.8	19																							19	0
9-22-77	N	L	2	11.5																								0	0
9-22-77	N	L	4	11.5	19																							19	0
9-22-77	N	L	6	11.2	19																							19	0
9-22-77	D	N	0	12.3																								0	0
9-22-77	D	N	2	11.1																								0	0
9-22-77	D	N	4	11.1																								0	0
9-22-77	D	N	6	11.1	18																							18	0
9-22-77	D	N	8	10.8																								0	0
9-22-77	N	N	0	12.1	38																							38	0
9-22-77	N	N	2	11.0																								0	0
9-22-77	N	N	4	11.0																								0	0
9-22-77	N	N	6	10.1	57																							57	0
9-22-77	N	N	8	10.1																								0	0
9-22-77	D	O	0	12.2	19																							19	0
9-22-77	D	O	3	9.9																								0	0
9-22-77	D	O	5	9.9																								0	0
9-22-77	D	O	9	9.9																								0	0
9-22-77	D	O	11	8.0																								0	0
9-22-77	N	O	0	12.0	18																							18	0
9-22-77	N	O	3	11.1																								0	0
9-22-77	N	O	6	11.1																								0	0
9-22-77	N	O	9	11.1	36																							36	0
9-22-77	N	O	11	9.0	14																							14	0

APPENDIX 7. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
9-21-77	D	Q	0	16.6																								0	0
9-21-77	D	Q	0	16.6	167																							167	0
9-21-77	N	Q	0	10.0																								0	0
9-21-77	N	Q	0	10.0																								0	0
9-21-77	D	R	0	12.2																								0	0
9-21-77	D	R	0	12.2																								0	0
9-21-77	N	R	0	12.0																								0	0
9-21-77	N	R	0	12.0																								0	0
10-20-77	D	Q	0	11.2																								0	0
10-20-77	D	Q	0	11.2																								0	0
10-19-77	N	Q	0	12.9																								0	0
10-19-77	N	Q	0	12.9																								0	0
10-20-77	D	R	0	14.0	686																							686	0
10-20-77	D	R	0	14.0																								0	0
10-19-77	N	R	0	10.0																								0	0
10-19-77	N	R	0	10.0																								0	0
10-31-77	D	Q	0	10.7																								0	0
10-31-77	D	Q	0	10.7																								0	0
11-2-77	N	Q	0	12.1																								0	0
11-2-77	N	Q	0	12.1																								0	0
10-31-77	D	R	0	15.5																								0	0
10-31-77	D	R	0	15.5																								0	0
11-2-77	N	R	0	11.8																								0	0
11-2-77	N	R	0	11.8																								0	0
12-16-77	D	L	0	0.6																								0	0

APPENDIX 8

APPENDIX 8. Number of fish larvae and eggs per 1000 m^3 for stations in Pigeon Lake (Figure 2) near the J. H. Campbell Plant, eastern Lake Michigan, June - December 1977. See Table 57 for definition of species codes. D = day, N = night.

					NUMBER OF LARVAE PER 1000 M^3																								
DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XN	YP.	RB	SP.	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
6-2-77	D	M	0	13.2	100																							100	0
6-2-77	D	M	2	13.2	117		30																					147	0
6-2-77	D	M	4	13.2	94																							94	0
6-1-77	N	M	0	10.3	335		34		34																			403	0
6-1-77	N	M	2	10.3	235				150						30													405	0
6-1-77	N	M	4	10.3		31																						31	0
6-1-77	D	S	0	11.2												375	563											938	0
6-1-77	D	S	0	11.2												187	187											374	0
6-1-77	N	S	0	11.0	2866	1432	358		717							179											GL:179	5731	0
6-1-77	N	S	0	11.0	1075	1790			358						179	895			179									4476	0
6-1-77	D	T	0	12.0	1302	186	931	186		186				5772				745									GL:372	8378	0
6-1-77	D	T	0	12.0	2976		2979	186		931				11731				558									GL:931	9732	0
6-1-77	N	T	0	16.6	1022	3071	2393	513		513				8887				171		171	171						GL:171	17083	0
6-1-77	N	T	0	16.6	1191	3239	3247	171	1190	684				7690				171		1026	341							19086	0
6-1-77	D	V	0	12.2																								0	0
6-1-77	D	V	0	12.2																								0	0
6-2-77	N	V	0	14.0	159				159																			318	0
6-2-77	N	V	0	14.0	159	159														159								477	0
6-2-77	D	X	0	14.8	651						62			93														806	0
6-2-77	N	X	0	10.3	217	217	31							93	93				62									713	0
6-2-77	D	Y	0	18.0	43		872							785														1700	0
6-3-77	N	Y	0	19.6		215								43														258	0
6-23-77	D	M	0	16.4																								0	0
6-23-77	D	M	2	15.5																								0	0
6-23-77	D	M	4	15.1																								0	557
6-23-77	N	M	0	16.5		59																						59	0
6-23-77	N	M	2	15.4		59	30																					89	0
6-23-77	N	M	4	14.5								42																42	0
6-23-77	D	S	0	17.5																								0	8961
6-23-77	D	S	0	17.5																								0	27419
6-23-77	N	S	0	17.8																								0	0
6-23-77	N	S	0	17.8		680																			680			1360	30612

APPENDIX 8. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
6-23-77	D	T	0	24.4		179				179																	BC:179 XL:716	1253	2330
6-23-77	D	T	0	24.4				358		358																		716	3584
6-23-77	N	T	0	21.8		1837			460	919																	XL:460 GL:1379	5055	0
6-23-77	N	T	0	21.8																								0	2083
6-23-77	D	V	0	21.4																								0	0
6-23-77	D	V	0	21.4																								0	0
6-23-77	N	V	0	20.0		533			533									533										1599	1600
6-23-77	N	V	0	20.0					2456																			2456	0
6-23-77	D	X	0	20.0	163																							163	0
6-23-77	N	X	0	18.5		93							31															124	0
6-23-77	D	Y	0	21.4	67																							67	0
6-23-77	N	Y	0	20.0																								0	15282

APPENDIX 8. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
7-7-77	D	M	0	23.6	6541	28																						6569	370
7-7-77	D	M	2	22.4	2418																							2418	0
7-7-77	D	M	4	22.4	4224																							4224	0
7-7-77	N	M	0	24.0	12265	909			213				91															13478	0
7-7-77	N	M	2	22.5	10067				1418																			11485	118
7-7-77	N	M	4	22.2	3624				379																			4003	0
7-7-77	D	S	0	23.0	687	1147			230						460													2524	25287
7-7-77	D	S	0	23.0	4848	1010																						5858	41414
7-7-77	N	S	0	23.0	2347	14115			16474																			32936	0
7-7-77	N	S	0	23.0	832				1458						208													2498	5208
7-7-77	D	T	0	28.0	179	179												2509										2867	3405
7-7-77	D	T	0	28.0		190																						190	571
7-7-77	N	T	0	28.0	179																							179	0
7-7-77	N	T	0	28.0		179									179													358	1075
7-7-77	D	V	0	28.0	716	358			179																		XB:179	1432	0
7-7-77	D	V	0	28.0	266																							266	0
7-7-77	N	V	0	28.0	179	7346							179															7704	179
7-7-77	N	V	0	28.0	283	2835							1135															4253	0
7-7-77	D	Y	0	27.0		52																						52	521
7-7-77	D	Y	0	27.0	201	129																						430	87
7-28-77	D	M	0	11.0					100																			100	0
7-28-77	D	M	2	10.0					94																			94	0
7-28-77	D	M	4	10.0																								0	0
7-28-77	N	M	0	11.7	81	81																						162	0
7-28-77	N	M	2	11.7																							XG:30	30	0
7-28-77	N	M	4	11.3																								0	0
7-28-77	D	S	0	11.6					27955						6272													34227	0
7-28-77	D	S	0	11.6		5371															8064							13435	0
7-26-77	N	S	0	15.6	7699	9312			335283				537		537												SB:179 XL:179 GL:1256	354980	1613
7-26-77	N	S	0	15.6	24899	8238			232064						1792												PS:179 XL:179 GL:358	267709	0

APPENDIX 8. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
7-28-77	D	T	0	25.0																								0	0
7-28-77	D	T	0	25.0																								0	0
7-28-77	N	T	0	19.0																							XL:537	537	0
7-28-77	N	T	0	19.0		520				520																		1040	0
7-28-77	D	V	0	23.0																								0	0
7-28-77	D	V	0	23.0																							CT:179	179	0
7-28-77	N	V	0	19.0	179	1611							358		523						896							3567	0
7-28-77	N	V	0	19.0	1611	179							717	179	2329						1254						XL:179	6448	0
7-28-77	D	X	0	20.5																								0	0
7-28-77	N	X	0	18.0	1865			31																			GN:155	2051	0
7-28-77	D	Y	0	23.5																								0	0
7-28-77	N	Y	0	21.8	172																							172	0

APPENDIX 8. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
8-14-77	D	M	0	23.5																									
8-14-77	D	M	2	23.3																								0	0
8-14-77	D	M	4	23.0																								0	0
8-14-77	N	M	0	23.7	2380																							0	0
8-14-77	N	M	2	22.2	72																							2380	0
8-14-77	N	M	4	22.2	3324																							72	0
																												3324	0
8-13-77	D	S	0	22.8	5548																								
						9713			247519																				
8-13-77	D	S	0	22.8	3759				110028																			262780	0
8-16-77	N	S	0	22.2	3224				16844																			113787	0
8-16-77	N	S	0	22.2	3222				64153																			20068	0
																												67375	0
8-13-77	D	T	0	23.4																									
8-13-77	D	T	0	23.4																								0	0
8-16-77	N	T	0	22.0																								0	0
8-16-77	N	T	0	22.0		179																						0	0
																												179	0
8-13-77	D	V	0	26.5																									
8-13-77	D	V	0	26.5																							XL:387	387	0
8-16-77	N	V	0	22.0		179			358																		XL:833	833	0
8-16-77	N	V	0	22.0	179																							537	0
																											XL:179	358	0
8-14-77	D	X	0	23.8																									
8-14-77	N	X	0	22.7	45				45																			0	0
																												90	0
8-13-77	D	Y	0	22.9																									
8-14-77	N	Y	0	23.2																								0	0
																												0	0

APPENDIX 8. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	NUMBER OF LARVAE PER 1000 M^3 AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
9-19-77	D	M	0	18.2																								0	0
9-19-77	D	M	2	18.0																								0	0
9-19-77	D	M	4	18.0																								0	0
9-19-77	N	M	0	18.8																								0	0
9-19-77	N	M	2	18.8	52																							52	0
9-19-77	N	M	4	18.5	136																							136	34
9-19-77	D	S	0	17.0	9142																							9142	0
9-19-77	D	S	0	17.0																								0	0
9-20-77	N	S	0	17.0					137																			137	0
9-20-77	N	S	0	17.0																								0	0
9-19-77	D	T	0	17.8																								0	0
9-19-77	D	T	0	17.8																								0	0
9-19-77	N	T	0	17.0																								0	0
9-19-77	N	T	0	17.0																								0	0
9-19-77	D	V	0	17.0																								0	0
9-19-77	D	V	0	17.0																								0	0
9-20-77	N	V	0	17.0																								0	0
9-20-77	N	V	0	17.0																								0	0
9-19-77	D	X	0	19.2																								0	0
9-19-77	N	X	0	18.6																								0	0
9-19-77	D	Y	0	19.2																								0	0
9-19-77	N	Y	0	13.0																								0	0

APPENDIX 8. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
10-17-77	D	M	0	11.0																								0	0
10-17-77	D	M	2	10.5																								0	0
10-17-77	D	M	4	10.0																								0	0
10-17-77	N	M	0	10.1																								0	0
10-17-77	N	M	2	9.9																								0	0
10-17-77	N	M	4	9.9																								0	0
10-18-77	D	S	0	10.2																								0	0
10-18-77	D	S	0	10.2																								0	0
10-18-77	N	S	0	11.2																								0	0
10-18-77	N	S	0	11.2																								0	0
10-18-77	D	T	0	9.6																								0	0
10-18-77	D	T	0	9.6																								0	0
10-17-77	N	T	0	10.2																								0	0
10-17-77	N	T	0	8.0																								0	0
10-18-77	D	V	0	9.6																								0	0
10-18-77	D	V	0	9.6																								0	0
10-17-77	N	V	0	11.2																								0	0
10-17-77	N	V	0	11.2																								0	0
10-17-77	D	X	0	11.0						26																	XL:26	52	0
10-17-77	N	X	0	10.0	90																							90	0
10-18-77	D	Y	0	9.0																								0	0
10-17-77	N	Y	0	8.0																								0	0

APPENDIX 8. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
11-1-77	D	M	0	11.0																								0	0
11-1-77	D	M	2	11.0	25																							25	0
11-1-77	D	M	4	11.0	24																							24	0
11-1-77	N	M	0	11.3	26																							26	0
11-1-77	N	M	2	11.3	38																							38	0
11-1-77	N	M	4	11.3																								0	0
11-1-77	D	S	0	11.5																								0	0
11-1-77	D	S	0	11.5																								0	0
11-1-77	N	S	0	11.0																								0	0
11-1-77	N	S	0	11.0																								0	0
11-1-77	D	T	0	10.9																								0	0
11-1-77	D	T	0	10.9																								0	0
11-1-77	N	T	0	11.0																								0	0
11-1-77	N	T	0	11.0																								0	0
11-1-77	D	V	0	12.6																								0	0
11-1-77	D	V	0	12.6																								0	0
11-1-77	N	V	0	12.5																								0	0
11-1-77	N	V	0	12.5																								0	0
11-1-77	D	X	0	11.2																								0	0
11-1-77	N	X	0	12.0																								0	0
11-1-77	D	Y	0	11.0																								0	0
11-1-77	N	Y	0	11.0																								0	0
12-7-77	D	M	0	2.4																								0	0
12-7-77	D	M	2	2.4																								0	0
12-7-77	D	M	4	2.4																								0	0
12-7-77	N	M	0	2.4																								0	0
12-7-77	N	M	2	2.4																								0	0
12-7-77	N	M	4	2.4																								0	0
12-7-77	D	X	0	0.3																								0	0
12-7-77	N	X	0	0.4																								0	0

APPENDIX 8. (continued)

INTAKE CANAL STATION Z

DATE	DIEL PERIOD	DEPTH (METERS)	TEMP. C	NUMBER OF LARVAE PER 1000 M^3 AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
6-02-77	D	0	13.0											25													25	0
6-02-77	D	2	13.0	116																							116	0
6-01-77	N	0	10.3	96	72																						168	0
6-02-77	N	2	10.3	429	66								33														528	0
6-23-77	D	0	16.8		25																					XL:25	50	0
6-23-77	D	2	15.5																								0	0
6-23-77	N	0	15.6																								0	0
6-23-77	N	2	15.6																								0	0
7-07-77	D	0	24.0	4274	27																						4301	0
7-07-77	D	2	23.0	5254										34													5288	1056
7-07-77	N	0	22.5	12862	1195																						14057	0
7-07-77	N	2	22.5	23498	552																						24050	765
7-28-77	D	0	12.2	60																							60	0
7-28-77	D	2	11.0																								0	0
7-28-77	N	0	13.2	72	25																						97	0
7-28-77	N	2	12.3	59																							59	0
8-13-77	D	0	25.1																								0	0
8-13-77	D	2	24.8	135																							135	0
8-14-77	N	0	22.5	70																							70	0
8-14-77	N	2	22.6	249																							249	0
9-19-77	D	0	18.3																								0	0
9-19-77	D	2	18.3																								0	0
9-19-77	N	0	18.9																								0	0
9-19-77	N	2	18.9	63																							63	0
10-17-77	D	0	11.0																								0	0
10-17-77	D	2	10.5																								0	0
10-17-77	N	0	10.0																								0	0
10-17-77	N	2	10.0																								0	0
11-2-77	D	0	9.8																								0	0
11-2-77	D	2	9.8																								0	0
11-1-77	N	0	11.5																								0	0
11-1-77	N	2	11.3																								0	0
12-7-77	D	0	3.5																								0	0
12-7-77	D	2	3.0																								0	0
12-7-77	N	0	2.5																								0	0
12-7-77	N	0	2.5																								0	0

APPENDIX 9

APPENDIX 9. Number of fish larvae and eggs per 1000 m^3 captured by sled tow at stations in Lake Michigan (Figure 1) near the J. H. Campbell Plant, eastern Lake Michigan, July - October 1977. See Table 57 for definition of species codes. D = day, N = night.

					NUMBER OF LARVAE PER 1000 M^3																							TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.		
7-20-77	D	A	1.5	8.9	504																							504	0
7-21-77	N	A	1.5	9.8	1084	525			265																			1874	38
7-20-77	D	B	3	8.1	72	180			397																			649	72
7-21-77	N	B	3	8.4	715																								
						10566			6791						522													18594	326
7-20-77	D	C	6	8.1	376																							376	224
7-21-77	N	C	6	7.0	746	48			49																			843	0
7-20-77	D	D	9	7.7	385										35													420	35
7-21-77	N	D	9	7.0	38																							38	0
7-20-77	D	E	12	6.0	475																							475	0
7-21-77	N	E	12	6.8	43																							43	0
7-20-77	D	F	15	7.5	146																							146	0
7-21-77	N	F	15	6.0	252																	36						288	0
7-20-77	D	G	18	6.1	64																							64	0
7-21-77	N	G	18	6.1																								0	0
7-20-77	D	H	21	6.8	28																							28	0
7-21-77	N	H	21	6.0																								0	0
7-21-77	D	P	1	--	180																							180	0
7-21-77	N	P	1	16.0	685	1886			2752																			5323	0
7-21-77	D	I	1.5	--	15884	333			4431																			20648	8364
7-21-77	D	J	3	7.5		2889																						2889	0
7-21-77	D	L	6	--	165																							165	298
7-21-77	D	N	9	--																								0	0
7-21-77	D	O	12	--																								0	0
7-21-77	D	Q	1	--	835				1673							167												2675	7863
7-21-77	N	Q	1	--	1372	274	274		274					274		549												3017	24719
7-21-77	D	R	1	--	5261	1053			2634																			8948	176

APPENDIX 9. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
					NUMBER OF LARVAE PER 1000 M^3																								
8-15-77	D	A	1.5	22.7																								0	0
8-15-77	D	B	3	22.1																								0	0
8-15-77	D	C	6	19.2																								0	0
8-15-77	D	D	9	20.8																								0	0
8-15-77	D	E	12	18.9	18																							18	0
8-15-77	D	F	15	16.2																								0	0
8-15-77	D	G	18	14.5	72																							72	0
8-15-77	D	H	21	16.5																								0	0
8-15-77	D	P	1	24.1																								0	0
8-15-77	D	I	1.5	23.2					39																			39	0
8-15-77	D	J	3	24.6	58																							58	0
8-15-77	D	L	6	20.8																								0	0
8-15-77	D	N	9	21.0																								0	0
8-15-77	D	O	12	17.8																								0	0
8-15-77	D	Q	1	24.7					190																			190	0

APPENDIX 9. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
9-21-77	D	A	1.5	9.0																								0	0
9-22-77	N	A	1.5	9.0																								0	0
9-21-77	D	B	3	9.0	69																							69	0
9-22-77	N	B	3	13.3																								0	0
9-21-77	D	C	6	8.0																								0	0
9-22-77	N	C	6	8.0	21																							21	0
9-21-77	D	D	9	7.2																								0	0
9-22-77	N	D	9	13.3																								0	0
9-21-77	D	E	12	6.9	62																							62	0
9-22-77	N	E	12	6.9																								0	0
9-21-77	D	F	15	6.3																								0	0
9-22-77	N	F	15	6.3																								0	0
9-21-77	D	G	18	6.7																								0	0
9-22-77	N	G	18	6.7																								0	0
9-21-77	D	H	21	6.3																								0	0
9-22-77	N	H	21	6.3																								0	0
9-21-66	D	P	1	13.3	82																							82	0
9-22-77	N	P	1	13.3																								0	0
9-21-77	D	I	1.5	17.5																								0	0
9-22-77	N	I	1.5	17.5																								0	0
9-21-77	D	J	3	9.8																		43						43	87
9-22-77	N	J	3	9.3																								0	0
9-21-77	D	L	6	8.4																		64						64	0
9-22-77	N	L	6	8.4																								0	0
9-21-77	D	N	9	7.4																								0	0
9-22-77	N	N	9	8.4																								0	0
9-21-77	D	O	12	6.8																								0	0
9-22-77	N	O	12	6.8								30																30	0
9-21-77	D	Q	1	18.4	2576																							2576	0
9-22-77	N	Q	1	10.0																								0	0

APPENDIX 9. (continued)

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	NUMBER OF LARVAE PER 1000 M^3 AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER LARVAE PER 1000 M^3	TOTAL NUMBER EGGS PER 1000 M^3
10-20-77	D	A	1.5	10.8																								0	0
10-20-77	D	B	3	10.8																								0	0
10-20-77	D	C	6	10.7	20																							20	0
10-20-77	D	D	9	11.2																								0	0
10-20-77	D	I	1.5	10.5	36																							36	0
10-20-77	D	J	3	10.5	21																							21	0
10-20-77	D	L	6	10.8																								0	0
10-20-77	D	N	9	10.4																								0	0

APPENDIX 10

APPENDIX 10. A weekly summary of fish larvae and eggs entrained by the J. H. Campbell Plant, July - December 1977. This summary includes average number of fish larvae and eggs per 1000 m^3 and average number of fish larvae and eggs entrained per diel period.

Date	depth (m)	intake temp. (C)	Avg. No. Larvae/1000 m^3 Alewife	Unident. Minnow	Yellow Perch	Unident. Poor Cond.	Golden Shiner	Spottail Shiner	Lepomis	Unident. Pisces	Rainbow Smelt	Carp	Pomoxis Sp.	Gizzard Shad	Misc.	Avg. No. eggs per 1000 m^3	Total Vol. pumped (1000 m^3)	Avg. No. eggs entrained per diel period	Avg. No. larvae entrained per diel period	
7-08-77	0	21.7	2243	116									27			357	1438.0	513,366	3,431,068	Day
7-08-77	0	21.7	2066	1926		9		17				35	9			1833	310.9	569,880	1,262,876	Night
7-08-77																	1748.9	1,083,246	4,693,944	Total
7-14-77	0	18.4	375	10		3							4			55	1403.7	77,204	550,250	Day
7-14-77	0	18.4	1592	544		2		7			5		28			2617	322.5	843,982	702,405	Night
7-14-77																	1726.2	921,186	1,252,655	Total
7-21-77	0	22.8	465	11		2										0	1326.4	0	634,019	Day
7-21-77	0	23.4	1223	864	4	12		21				27	30		TP 4	0	331.6	0	724,546	Night
7-21-77																	1658.0	0	1,358,565	Total
7-29-77	0	12.5	20													3	1452.0	4,356	29,040	Day
7-29-77	0	12.5	26					3							XE 3	0	384.0	0	13,440	Night
7-29-77																	1836.0	4,356	42,480	Total
8-03-77	0	18.3	446	2				2								0	1411.5	0	635,175	Day
8-03-77	0	19.4	2398	14				20			5					0	375.2	0	914,362	Night
8-03-77																	1786.7	0	1,549,537	Total
8-10-77	0	22.8	1004					5								0	1296.6	0	1,308,269	Day
8-10-77	0	22.8	1108					15	2							0	422.0	0	474,750	Night
8-10-77																	1718.6	0	1,783,019	Total
8-16-77	0	21.1	30													0	1291.4	0	38,742	Day
8-16-77	0	21.2	53	2				2			5					0	484.0	0	30,008	Night
8-16-77																	1775.4	0	68,750	Total
8-22-77	0	18.3	11													0	1163.1	0	12,794	Day
8-22-77	0	18.3	9													0	464.6	0	4,181	Night
8-22-77																	1627.7	0	16,975	Total
9-01-77	0	21.7	32													0	1213.8	0	38,842	Day
9-01-77	0	21.1	37								2					0	474.3	0	18,498	Night
9-01-77																	1688.1	0	57,340	Total
9-08-77	0	16.1	29													0	1189.5	0	34,496	Day
9-08-77	0	15.6	25													0	566.9	0	14,173	Night
9-08-77																	1756.4		48,669	Total

APPENDIX 10. (continued)

Date	depth (m)	intake temp. (C)	Avg. No. Larvae/1000 m^3: Alewife	Unident. Minnow	Yellow Perch	Unident. Poor Cond.	Golden Shiner	Spottail Shiner	*Lepomis* sp	Unident. Pisces	Rainbow Smelt	Carp	*Pomoxis* Sp.	Gizzard Shad	Misc.	Avg. No. eggs per 1000 m^3	Total Vol. pumped (1000 m^3)	Avg. No. eggs entrained per diel period	Avg. No. larvae entrained per diel period	
9-19-77	0	18.4	31													0	602.8	0	18,687	Day
9-19-77	0	18.4	26													0	349.6	0	8,440	Night
9-19-77																	927.4		27,127	Total
9-28-77	0	16.1														0	384.0	0	0	Day
9-28-77	0	16.1	7													0	225.5	0	1,579	Night
9-28-77																	609.5	0	1,579	Total
10-06-77	0	11.7														0	1108.4	0	0	Day
10-06-77	0	11.7		1												0	708.6	0	709	Night
10-06-77																	1817.0	0	709	Total
10-13-77	0	11.1														0	569.6	0	0	Day
10-13-77	0	10.6	1													0	373.0	0	373	Night
10-13-77																	942.6	0	373	Total
10-18-77	0	11.1	9													0	507.0	0	4,563	Day
10-18-77	0	10.0	10								2					0	352.3	0	4,228	Night
10-18-77																	859.3	0	8,791	Total
10-25-77	0	11.7														0	1242.7	0	0	Day
10-25-77	0	11.7	8													0	937.5	0	7,500	Night
10-25-77																	2180.2	0	7,500	Total
11-02-77	0	11.7	7													0	1382.0	0	9,674	Day
11-02-77	0	12.2	8													0	1085.8	0	8,686	Night
11-02-77																	2467.8	0	18,360	Total
11-07-77	0	10.0														0	1375.6	0	0	Day
11-07-77	0	10.0														0	1080.9	0	0	Night
11-07-77																	2465.5	0	0	Total
11-14-77	0	7.2														0	1058.5	0	0	Day
11-14-77	0	7.2														0	902.1	0	0	Night
11-14-77																	1960.6	0	0	Total
11-21-77	0	6.1														0	1312.2	0	0	Day
11-21-77	0	6.1	3													0	1117.0	0	3,351	Night
11-21-77																	2430.0	0	3,351	Total
11-28-77	0	5.6														0	605.8	0	0	Day
11-28-77	0	5.6														0	537.3	0	0	Night
11-28-77																	1143.1	0	0	Total

APPENDIX 10. (continued)

Date	depth (m)	intake temp. (C)	Avg. No. Larvae/1000 m^3 Alewife	Unident. Minnow	Yellow Perch	Unident. Poor Cond.	Golden Shiner	Spottail Shiner	Lepomis	Unident. Pisces	Rainbow Smelt	Carp	Pomoxis Sp.	Gizzard Shad	Misc.	Avg. No. eggs per 1000 m^3	Total Vol. pumped (1000 m^3)	Avg. No. eggs entrained per diel period	Avg. No. larvae entrained per diel period	
12-07-77	0	2.2														0	625.9	0	0	Day
12-07-77	0	2.2														0	577.7	0	0	Night
12-07-77																	1203.6	0	0	Total
12-12-77	0	8.3														0	622.0	0	0	Day
12-12-77	0	4.4														0	574.1	0	0	Night
12-12-77																	1196.1	0	0	Total

APPENDIX 11

APPENDIX 11. Number of fish fry caught during larvae sampling near the J. H. Campbell Plant, eastern Lake Michigan (Figures 1 and 2), June - December 1977. See table 57 for definition of species codes. D = day, N = night. * denotes sled tow sample.

LAKE MICHIGAN AND PIGEON LAKE

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER FRY PER 1000 M^3
					NUMBER OF FRY PER 1000 M^3																							
06-01-77	N	S	0	11.0																179	537							716
06-02-77	N	T	0	16.6			1025														170						MT:170	1365
06-02-77	N	T	0	16.6			2564														170							2734
06-02-77	D	Y	0	18.0			30																					30
06-17-77	N	L	0	16.5	27																							27
06-22-77	N	P	0	16.0					281																			281
06-23-77	N	T	0	21.8			625		833																			1458
06-23-77	D	T	0	24.4			537	179		179																		1074
06-23-77	N	T	0	21.8			1379			919																	GL:1839	4137
07-07-77	N	M	0	24.0	60																							60
07-07-77	N	S	0	23.0																							ES:156	156
07-07-77	D	T	0	28.0		179																						179
07-07-77	N	T	0	28.0			179		179																		BC: 179	527
07-07-77	N	T	0	28.0					179																		GL:1971	2150
07-09-77	D	C	0	22.0	14																							14
07-09-77	N	I	0	19.0	20																							20
07-07-77	N	R	0	24.2					147																			147
07-13-77	N	J	0	24.0	33																							23
07-13-77	N	L	0	18.5	22																							22
7-13-77	N	N	0	23.3	65																							65
07-13-77	N	O	0	21.5	74																							74
07-13-77	N	O	5	20.0								25																25
07-13-77	D	R	0	29.0	128																							128
07-13-77	N	R	0	29.0	476																							476
07-14-77	N	R	0	29.0	485																							485
07-21-77	N	A*	1.5	9.8		37																						37
07-21-77	N	B*	3	8.4	65																							65
07-21-77	N	E*	12	6.8								130																130
07-22-77	N	F*	15	6.0								72																72
07-20-77	D	G*	18	6.1					32																			32
07-21-77	N	P*	1	16.0	171																							171
07-28-77	N	M	0	11.7	81																							81
07-28-77	D	S	0	11.6					358																			358
07-28-77	D	S	0	11.6																	179							179
07-26-77	N	S	0	15.6	537		179		716																			1432
07-26-77	N	S	0	15.6	2688		179		358																			3225
07-26-77	N	T	0	19.0			179																				GL:1254 BC:179	1612
07-26-77	N	T	0	19.0																							GL:2083	2083
07-28-77	D	V	0	23.0	179																							179
07-28-77	N	X	0	18.0	467																							467
07-28-77	N	Y	0	21.8	130																							130

APPENDIX 11. (continued)

LAKE MICHIGAN AND PIGEON LAKE

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER FRY PER 1000 M^3
					NUMBER OF FRY PER 1000 M^3																							
07-28-77	D	Z	2	11.0									19															19
07-28-77	N	Z	0	13.2	24																							24
07-28-77	N	Z	2	12.3	58																							58
07-28-77	N	A	0	13.0	130																							130
07-28-77	N	B	0	13.0	22																							22
07-27-77	D	C	2	7.2								30																30
07-27-77	D	C	6	7.4	18																							18
07-28-77	N	C	6	10.4								47																47
07-27-77	N	H	9	6.5	20																							20
07-28-77	N	L	4	10.7	24																							24
07-28-77	N	L	6	9.6	43																							43
07-28-77	N	N	6	11.3								59																59
07-25-77	N	P	0	16.0	427				162																			589
07-25-77	N	P	0	16.0					141																			141
07-25-77	N	Q	0	20.0	3703				246																			3844
07-25-77	N	Q	0	20.0	3619				190																			3809
07-25-77	N	R	0	17.0	170				854																			1024
08-14-77	N	M	4	22.2	792																							792
08-13-77	D	S	0	22.8					277																			277
08-13-77	D	S	0	22.8	179				896																			1075
08-16-77	N	S	0	22.2																								
					15591				28494																			44085
08-16-77	N	S	0	22.2	6093				8422												179							14694
08-16-77	N	T	0	22.0																							GL:179 XB:179	358
08-16-77	N	T	0	22.0														179									GL:358 BN:179	716
08-13-77	D	V	0	26.5					387																			387
08-16-77	N	V	0	22.0	179	179	179		358																			895
08-16-77	N	V	0	22.0																	716							716
08-14-77	N	X	0	22.7	45																							45
08-16-77	N	A	0	20.0	1136																							1136
08-16-77	N	B	0	20.0	509																							509
08-16-77	N	B	2	19.4	285																							285
08-18-77	N	C	0	17.0	88							29																117
08-18-77	N	C	2	12.0	16							16																32
08-18-77	N	C	4	12.0								38																38
08-18-77	N	C	6	5.0								19																19
08-18-77	N	D	0	15.1	18							18																36
08-18-77	N	D	2	12.2	18							55																73

APPENDIX 11. (continued)

LAKE MICHIGAN AND PIGEON LAKE

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER FRY PER 1000 M^3
					NUMBER OF FRY PER 1000 M^3																							
08-18-77	N	D	4	12.2								128																128
08-18-77	N	D	6	12.2								19																19
08-18-77	N	D	8	5.0								19																19
08-18-77	D	E	11	5.0								39																39
08-18-77	N	E	3	12.2								18																18
08-18-77	N	E	6	12.2								76																76
08-18-77	N	E	9	12.2								78																78
08-18-77	N	E	11	4.6								73																73
08-15-77	D	F*	15	16.2								38																38
08-18-77	N	F	8	6.0								60																60
08-18-77	N	F	12	6.0								93																93
08-18-77	N	F	14	4.8								98																98
08-15-77	D	G*	18	14.5								36																36
08-15-77	D	H*	21	16.5								126																126
08-16-77	N	I	0	21.4	192																							192
08-16-77	N	J	0	21.4	852																							852
08-16-77	N	J	2	20.9	29																							29
08-19-77	D	L	2	15.2								22																22
08-18-77	N	L	0	13.1	652																							652
08-18-77	N	L	2	8.5	1214																							1214
08-18-77	N	L	4	8.5	250							77																327
08-18-77	N	L	6	5.2	170							37																207
08-18-77	N	N	0	14.5	253																							253
08-18-77	N	N	2	6.0	690							18																708
08-19-77	N	N	4	6.0	55							83																138
08-19-77	N	N	6	6.0	35							53																88
08-19-77	N	N	8	5.1	53							17																70
08-19-77	D	O	0	10.0								24																24
08-19-77	N	O	0	16.2	18							18																36
08-19-77	N	O	6	15.0	18							132																150
08-19-77	N	O	9	5.5								31																31
08-19-77	N	O	11	5.5								37																37
08-16-77	D	P	0	24.1	51																							51
08-16-77	N	P	0	21.5	292																							292
08-16-77	N	P	0	21.5	120																							120
08-15-77	D	Q*	1	24.7					63																			63
08-16-77	N	Q	0	20.6	275																							275
08-15-77	D	R	0	24.4	2485																							2485
08-15-77	D	R	0	24.4	3801																							3801
09-19-77	N	M	2	18.8	26																							26
09-19-77	N	M	5	18.5	469																							469
09-20-77	N	S	0	17.0	549				549																			1098
09-20-77	N	S	0	17.2	358				537																			895
09-19-77	N	Z	0	18.9	41																							41
09-19-77	N	Z	2	18.9	21																							21

APPENDIX 11. (continued)

LAKE MICHIGAN AND PIGEON LAKE

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER FRY PER 1000 M^3
					NUMBER OF FRY PER 1000 M^3																							
09-22-77	D	A	0	12.5	33																							33
09-22-77	D	B	2	12.5	10																							10
09-22-77	N	B*	3	13.3					75			50																125
09-22-77	N	C	6	12.3								31																31
09-22-77	N	D	8	10.7	15																							15
09-22-77	N	E	0	12.5	38																							38
09-22-77	N	E	3	9.3	18																							18
09-22-77	N	E	6	9.3	17																							17
09-22-77	N	E	9	9.3	15																							15
09-22-77	N	E*	12	6.9								33																33
09-22-77	N	F	4	8.3	18																							18
09-22-77	N	F	8	8.3	14																							14
09-22-77	N	F	12	8.3	15																							15
09-22-77	N	F	15	8.3	12							12																24
09-21-77	D	I*	1.5	17.5	19				57																		• PS:19	95
09-23-77	N	I	0	10.1	26																							26
09-22-77	N	I*	1.5	17.5	579				121																		BG:30	730
09-22-77	D	J	2	9.3	14																							14
09-21-77	D	J*	3	9.3					43																			43
09-22-77	N	J	0	10.1	26																							26
09-23-77	N	J	2	9.3	26																							26
09-22-77	N	J*	3	9.3	35																							35
09-22-77	N	L*	6	8.4					84																			84
09-22-77	N	N	6	11.0	37																							37
09-22-77	N	N*	9	11.0					41			124								41								206
09-22-77	N	O	3	11.1	18																							18
09-22-77	N	O	6	11.1	17																							17
09-22-77	N	O	9	11.1	54																							54
09-22-77	N	O	12	9.0	41							27																68
09-22-77	N	O*	12	9.0								91																91
09-21-77	D	P*	1	13.3					164																			164
09-22-77	N	Q*	1	10.0	255				255																			510
09-22-77	N	R	0	12.0					162																			162
10-17-77	N	M	2	9.8	45																							45
10-17-77	N	M	4	9.9	78							26																94
10-17-77	N	S	0	11.2					471																			471
10-17-77	N	S	0	11.2																							BG:197	197
10-18-77	D	T	0	9.6																							BG:171	171
10-18-77	D	T	0	9.6						166																		166
10-17-77	N	T	0	8.0			444																					444
10-17-77	N	T	0	8.0			275																					275
10-17-77	N	X	0	10.0																							XL:45	45
10-17-77	N	Z	0	10.0	30																							30
10-17-77	N	Z	2	10.0								32																32

APPENDIX 11. (continued)

LAKE MICHIGAN AND PIGEON LAKE

DATE	DIEL PERIOD	STATION	DEPTH (METERS)	TEMP. C	NUMBER OF FRY PER 1000 M^3 AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER FRY PER 1000 M^3
10-29-77	D	I*	1.5	10.5	18																							18
10-20-77	D	J*	3	10.5	15																							15
10-19-77	N	P	0	10.5	182																							182
10-19-77	N	Q	0	12.9	1092																							1092
10-19-77	N	Q	0	12.9	596																							596
10-20-77	D	R	0	14.0	343																							343
11-01-77	D	M	0	11.0	21																							21
11-01-77	N	M	2	11.1	19																							19
11-01-77	N	M	4	11.3	174																							174
11-01-77	N	T	0	11.0			493																					493
11-01-77	D	V	0	12.6		303																					XL:606	909
11-01-77	N	Z	0	11.5	22																							22
12-07-77	N	M	4	2.4	19																							19

APPENDIX 11. (continued)

FRY ENTRAINED BY THE J. H. CAMPBELL PLANT

DATE	DIEL PERIOD	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER FRY PER 1000 M^3
				NUMBER OF FRY PER 1000 M^3																							
07-07-77	N	0	21.7												14												14
07-07-77	N	0	21.7												14												14
07-14-77	N	0	18.4	18							4																27
07-14-77	N	0	18.4	26																							26
07-20-77	N	0	23.4								17																17
07-29-77	D	0	12.5	21																							21
07-29-77	D	0	12.5	34																							34
07-29-77	D	0	12.5	10																							10
07-29-77	D	0	12.5	24																							24
07-29-77	N	0	12.5	63																							63
07-29-77	N	0	12.5	181				11																			192
07-29-77	N	0	12.5	128																							128
08-04-77	D	0	18.3	267																							267
08-04-77	D	0	18.3	188																							188
08-04-77	D	0	18.3	208							9																217
08-04-77	D	0	18.3	109																							109
08-03-77	N	0	19.4	119				19			39																177
08-03-77	N	0	19.4	228							29																257
08-03-77	N	0	19.4	287																							287
08-03-77	N	0	19.4	109							39																148
08-10-77	D	0	22.8	655																							655
08-10-77	D	0	22.8	446																							446
08-10-77	D	0	22.8	2193																							2193
08-10-77	D	0	22.8	764																							764
08-10-77	N	0	22.8	1697							9																1706
08-10-77	N	0	22.8	1915							39																1954
08-10-77	N	0	22.8	1915							29																1944
08-10-77	N	0	22.8	1260																							1260
08-16-77	D	0	21.1											11													11
08-16-77	D	0	21.1	129																							129
08-16-77	D	0	21.1	26																							86
08-16-77	N	0	21.2	36																							36
08-16-77	N	0	21.2	97																							97
08-16-77	N	0	21.2	94							18																112
08-16-77	N	0	21.2	35				8			8																51
08-16-77	N	0	21.2	75							9																84
08-22-77	D	0	18.3	9							9																18
08-22-77	D	0	18.3	29				9																			38
08-22-77	D	0	18.3	9																							9
08-22-77	D	0	18.3	19																							19
08-23-77	N	0	18.3	9				9			49																67
08-23-77	N	0	18.3	9							29																38

APPENDIX 11. (continued)

FRY ENTRAINED BY THE J. H. CAMPBELL PLANT NUMBER OF FRY PER 1000 M^3

DATE	DIEL PERIOD	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER FRY PER 1000 M^3
08-23-77	N	0	18.3	49							79																128
08-23-77	N	0	18.3	9							69																78
09-01-77	D	0	21.7	19																							19
09-01-77	D	0	21.7	9				9																			18
09-02-77	D	0	21.1	89							109																198
09-02-77	N	0	21.1	9							29																38
09-02-77	N	0	21.1								29																29
09-02-77	N	0	21.1	9							39																48
09-08-77	D	0	16.1	109							9																118
09-08-77	D	0	16.1	178																							178
09-08-77	D	0	16.1	215																							215
09-08-77	D	0	16.1	645																							645
09-09-77	N	0	15.6	9							9																18
09-09-77	N	0	15.6	9																							9
09-09-77	N	0	15.6	9																							9
09-09-77	N	0	15.6	9																							9
09-19-77	D	0	18.4	10																							10
09-19-77	D	0	18.4	21																							21
09-19-77	D	0	18.4																							BG:10	10
09-19-77	N	0	18.4	20																							20
09-19-77	N	D	18.4	11																							11
09-19-77	N	0	18.4	10																							10
09-28-77	D	0	16.1	27																							27
09-28-77	D	0	16.1	27																							27
09-28-77	D	0	16.1	28																							28
09-28-77	N	0	16.1	17																							17
09-28-77	N	0	16.1	53																							13
10-06-77	D	0	11.7	29																							29
10-06-77	D	0	11.7	35																							35
10-06-77	D	0	11.7	30																							30
10-07-77	N	0	11.7	6				6																			12
10-07-77	N	0	11.7	39							9																48
10-07-77	N	0	11.7	23							15																39
10-07-77	N	0	11.7	48				12			36																96
10-13-77	D	0	11.1	7																							7
10-13-77	D	0	11.1	27																							27
10-13-77	D	0	11.1	8																							8
10-13-77	D	0	11.1	8																							8
10-14-77	N	0	11.7											7													7
10-14-77	N	0	11.7	18																							18
10-14-77	N	0	11.7	26																							26
10-14-77	N	0	11.7	11																							11

APPENDIX 11. (continued)

FRY ENTRAINED BY THE J. H. CAMPBELL PLANT

DATE	DIEL PERIOD	DEPTH (METERS)	TEMP. C	AL	XM	YP	RB	SP	LB	XX	SM	CP	PM	XP	NS	XH	SV	XE	JD	BM	TP	SS	XC	XG	BR	MISC.	TOTAL NUMBER FRY PER 1000 M^3
				NUMBER OF FRY PER 1000 M^3																							
10-18-77	D	0	11.1	22																							22
10-18-77	D	0	11.1	9																							9
10-18-77	D	0	11.1	9																							9
10-18-77	N	0	10.0	9																							9
10-18-77	N	0	10.0	13							13																26
10-18-77	N	0	10.0	9																							9
10-25-77	D	0	11.7	12																							12
10-26-77	N	0	11.7	22																							22
10-26-77	N	0	11.7					9																		GS:18	27
10-26-77	N	0	11.7								10																10
10-26-77	N	0	11.7	12							12																24
11-02-77	D	0	11.7	28																							28
11-02-77	N	0	12.2	29																							29
11-02-77	N	0	12.2	12				12																			24
11-02-77	N	0	12.2	85																							85
11-02-77	N	0	12.2	28																							28
11-07-77	D	0	10.0	26																							26
11-07-77	D	0	10.0	96																							96
11-07-77	D	0	10.0	20																							20
11-07-77	N	0	10.0	32																							32
11-07-77	N	0	10.0	29																							29
11-14-77	N	0	7.2					17																			17
11-21-77	N	0	6.1								21																21
11-21-77	N	0	6.1					10																			10
11-28-77	D	0	5.6																							ES:16	16

APPENDICES 12 and 13

APPENDIX 12. Abundance ($\#/m^2$) and percent composition of major benthos taxonomic groups collected from Lake Michigan near the J.H. Campbell Plant, August 1977 ($\bar{X}$ = mean, S.E. = standard error).

Depth Zone: 3 meters

Taxa	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Chironomidae	1381.68	191.06	97.44	1575.60	657.73	90.28	2254.32	267.19	83.78	1737.20	264.55	89.03
Naididae	24.24	24.24	1.71	60.60	33.19	3.47	351.48	163.06	13.06	145.44	103.55	7.45
Tubificidae	12.12	12.12	0.85							4.04	4.04	0.21
S. heringianus				12.12	12.12	0.69	48.48	22.67	1.80	20.20	14.57	1.04
Enchytraeidae												
P. affinis				24.24	24.24	1.39	36.36	24.24	1.35	20.20	10.69	1.04
Pelecypoda				36.36	24.24	2.08				12.12	12.12	0.62
Gastropoda				36.36	24.24	2.08				12.12	12.12	0.62
Hirudinea												
Total Animals	1418.04	202.44		1745.28	752.12		2690.64	399.96		1951.32	381.54	

Depth Zone: 6 meters

Taxa	North Region			Middle Region			South Region			Total		
	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%	$\bar{X}$	S.E.	%
Chironomidae	4181.40	409.22	40.83	1212.00	345.47	66.23	2048.28	511.85	22.59	2480.56	884.02	35.21
Naididae	1539.24	102.48	15.03	266.64	134.96	14.57	2169.48	488.72	23.93	1325.12	559.64	18.81
Tubificidae	4326.84	1257.30	42.25	290.88	120.29	15.89	4532.88	1029.20	50.00	3050.20	1380.94	43.29
S. heringianus				12.12	12.12	0.66				4.04	4.04	0.06
Enchytraeidae												
P. affinis	84.84	14.84	0.83				84.84	30.90	0.94	56.56	28.28	0.80
Pelecypoda	72.72	12.12	0.71	48.48	35.34	2.65	121.20	50.70	1.34	80.80	21.38	1.15
Gastropoda	24.24	14.84	0.24				12.12	12.12	0.13	12.12	7.00	0.17
Hirudinea												
Total Animals	10241.40	1407.30		1830.12	491.72		9065.76	1965.22		7045.76	2629.81	

APPENDIX 12. (continued)

Depth Zone: 9 meters

Taxa	North Region $\bar{X}$	North Region S.E.	North Region %	Middle Region $\bar{X}$	Middle Region S.E.	Middle Region %	South Region $\bar{X}$	South Region S.E.	South Region %	Total $\bar{X}$	Total S.E.	Total %
Chironomidae	1369.56	183.41	17.10	969.60	83.53	16.19	1224.12	214.60	16.26	1187.76	116.88	16.55
Naididae	1805.88	285.79	22.54	2581.56	384.99	43.12	2108.88	241.18	28.02	2165.44	225.70	30.18
Tubificidae	3732.96	617.88	46.60	1539.24	399.04	25.71	3054.24	252.49	40.58	2775.48	648.43	38.68
S. heringianus				36.36	24.24	0.61	36.36	24.24	0.48	24.24	12.12	0.34
Enchytraeidae												
P. affinis	606.00	50.70	7.56	606.00	91.90	10.12	593.88	105.66	7.89	601.96	4.04	8.39
Pelecypoda	290.88	61.80	3.63	169.68	29.69	2.83	387.84	45.35	5.15	282.80	63.11	3.94
Gastropoda	169.68	52.13	2.12	72.72	22.67	1.21	60.60	27.10	0.81	101.00	34.52	1.41
Hirudinea												
Total Animals	3011.32	855.17		5987.28	476.93		7526.52	559.16		7175.04	610.15	

Depth Zone: 12 meters

Taxa	North Region $\bar{X}$	North Region S.E.	North Region %	Middle Region $\bar{X}$	Middle Region S.E.	Middle Region %	South Region $\bar{X}$	South Region S.E.	South Region %	Total $\bar{X}$	Total S.E.	Total %
Chironomidae	957.48	154.97	9.15	618.12	103.91	8.02	509.04	136.32	5.68	694.88	135.02	7.68
Naididae	1102.92	192.02	10.54	1175.64	195.05	15.25	2399.76	646.63	26.76	1559.44	420.68	17.24
Tubificidae	2727.00	564.91	26.07	1175.64	272.77	15.25	2933.04	275.45	32.70	2278.56	554.66	25.19
S. heringianus												
Enchytraeidae												
P. affinis	1890.72	263.73	18.08	1054.44	114.34	13.68	1563.48	185.20	17.43	1502.88	243.31	16.61
Pelecypoda	2739.12	424.81	26.19	2933.04	555.61	38.05	957.48	196.74	10.68	2209.88	628.70	24.43
Gastropoda	896.88	179.15	8.57	702.96	91.10	9.12	157.56	49.23	1.76	585.80	221.32	6.48
Hirudinea	12.12	12.12	0.12				12.12	12.12	0.14	8.08	4.04	0.09
Total Animals	10459.56	944.97		7708.32	789.99		8968.80	919.64		9045.56	795.14	

APPENDIX 12. (continued)

Depth Zone: 15 meters

Taxa	North Region $\bar{X}$	North Region S.E.	North Region %	Middle Region $\bar{X}$	Middle Region S.E.	Middle Region %	South Region $\bar{X}$	South Region S.E.	South Region %	Total $\bar{X}$	Total S.E.	Total %
Chironomidae	315.12	105.66	1.98	254.52	29.69	1.81	666.60	116.57	5.04	412.08	128.46	2.87
Naididae	739.32	212.88	4.65	630.24	123.60	4.49	921.12	212.88	6.97	763.56	84.84	5.31
Tubificidae	2351.28	489.10	14.80	981.72	92.70	6.99	4266.24	542.23	32.26	2533.08	952.51	17.61
S. heringianus	763.56	166.62	4.81	1127.16	210.45	8.02	193.92	84.41	1.47	694.88	271.58	4.83
Enchytraeidae												
P. affinis	6459.96	638.06	40.66	5660.04	465.32	40.29	3393.60	610.53	25.66	5171.20	918.31	35.96
Pelecypoda	4023.84	761.39	25.33	4738.92	573.75	33.74	2848.20	886.71	21.54	3870.32	551.18	26.91
Gastropoda	1102.92	412.97	6.94	593.88	137.39	4.23	254.52	77.61	1.92	650.44	246.54	4.52
Hirudinea	36.36	14.84	0.23	24.24	14.84	0.17	36.36	24.24	0.27	32.32	4.04	0.22
Total Animals	15877.20	2557.87		14047.08	864.78		13222.92	2079.51		14382.40	784.35	

Depth Zone: 20 meters

Taxa	North Region $\bar{X}$	North Region S.E.	North Region %	Middle Region $\bar{X}$	Middle Region S.E.	Middle Region %	South Region $\bar{X}$	South Region S.E.	South Region %	Total $\bar{X}$	Total S.E.	Total %
Chironomidae	618.12	92.70	4.67	472.68	48.48	5.17	387.84	86.98	4.91	492.88	67.24	4.88
Naididae	1284.72	360.76	9.71	1296.84	298.11	14.19	957.48	260.93	12.12	1179.68	111.16	11.69
Tubificidae	1805.88	928.27	13.64	242.40	108.40	2.65	1575.60	275.05	19.94	1207.96	487.34	11.97
S. heringianus	2896.68	428.25	21.89	2702.76	552.62	29.58	448.44	112.72	5.67	2015.96	785.76	19.98
Enchytraeidae												
P. affinis	4969.20	552.76	37.55	2920.92	322.61	31.96	2460.36	347.91	31.13	3450.16	771.07	34.19
Pelecypoda	1369.56	174.17	10.35	1199.88	330.48	13.13	1054.44	330.03	13.34	1207.96	91.06	11.97
Gastropoda	109.08	40.20	0.82	290.88	145.19	3.18	169.68	70.15	2.15	189.88	53.44	1.88
Hirudinea	12.12	12.12	0.09							4.04	4.04	0.04
Total Animals	13235.04	1491.50		9138.48	732.08		7902.24	1103.79		10091.92	1611.57	

APPENDIX 12. (continued)

Taxa	North Region $\bar{X}$	North Region S.E.	North Region %	Middle Region $\bar{X}$	Middle Region S.E.	Middle Region %	South Region $\bar{X}$	South Region S.E.	South Region %	Total $\bar{X}$	Total S.E.	Total %
Depth Zone: 25 meters												
Chironomidae	593.88	146.45	5.76	327.24	30.90	3.67	436.32	130.54	4.66	452.48	77.40	4.75
Naididae	1296.84	169.90	12.59	72.72	44.53	0.82	678.72	216.30	7.24	682.76	353.38	7.17
Tubificidae	884.76	226.42	8.59	581.76	119.06	6.53	1914.96	221.50	20.44	1127.16	403.49	11.83
S. heringianus	1999.80	201.90	19.41	4193.52	468.39	47.07	993.84	217.32	10.61	2395.72	944.64	25.15
Enchytraeidae												
P. affinis	3636.00	515.63	35.29	2690.64	210.45	30.20	3126.96	308.17	33.38	3151.20	273.17	33.08
Pelecypoda	1175.64	322.15	11.41	824.16	98.84	9.25	1248.36	492.91	13.32	1082.72	130.97	11.37
Gastropoda	109.08	82.20	1.06				48.48	22.67	0.52	52.52	31.55	0.55
Hirudinea												
Total Animals	10302.00	515.99		8908.20	747.37		9368.76	916.76		9526.32	410.00	

Appendix 13. Abundance ($\#/m^2$) and percent composition of major benthos taxonomic groups collected from Lake Michigan near the J.H. Campbell Plant, October 1977 ($\bar{X}$ = mean, S.E. = standard error).

Taxa	North Region $\bar{X}$	North Region S.E.	North Region %	Middle Region $\bar{X}$	Middle Region S.E.	Middle Region %	South Region $\bar{X}$	South Region S.E.	South Region %	Total $\bar{X}$	Total S.E.	Total %
Depth Zone: 3 meters												
Chironomidae												
Naididae												
Tubificidae												
S. heringianus												
Enchytraeidae												
P. affinis	739.32	393.85	100.00	60.60	27.10	100.00	109.08	29.69	100.00	303.00	218.61	100.00
Pelecypoda												
Gastropoda												
Hirudinea												
Total Animals	739.32	393.85		60.60	27.10		109.08	29.69		303.00	218.61	

APPENDIX **13.** (continued)

Depth Zone: 6 meters

Taxa	North Region			Middle Region			South Region			Total		
	$\overline{X}$	S.E.	%	$\overline{X}$	S.E.	%	$\overline{X}$	S.E.	%	$\overline{X}$	S.E.	%
Chironomidae	3575.40	569.45	73.20	1539.24	596.41	94.78	3284.52	416.95	55.53	2799.72	635.81	67.61
Naididae	242.40	101.40	4.96	12.12	12.12	0.75	715.08	246.46	12.09	323.20	206.91	7.80
Tubificidae	812.04	269.38	16.63				1818.00	409.67	30.74	876.68	525.81	21.17
S. heringianus	12.12	12.12	0.25							4.04	4.04	0.10
Enchytraeidae												
P. affinis	60.60	27.10	1.24	36.36	14.84	2.24	36.36	14.84	0.61	44.44	8.08	1.07
Pelecypoda	84.84	14.84	1.74	24.24	24.24	1.49	60.60	27.10	1.02	56.56	17.61	1.36
Gastropoda	96.96	24.24	1.99	12.12	12.12	0.75				36.36	30.50	0.88
Hirudinea												
Total Animals	4884.36	905.48		1624.08	617.23		5914.56	963.06		4141.00	1293.12	

Depth Zone: 9 meters

Taxa	North Region			Middle Region			South Region			Total		
	$\overline{X}$	S.E.	%	$\overline{X}$	S.E.	%	$\overline{X}$	S.E.	%	$\overline{X}$	S.E.	%
Chironomidae	4096.56	219.00	42.36	3575.40	430.64	44.16	3975.36	257.53	49.25	3882.44	157.46	45.08
Naididae	1345.32	208.52	13.91	1102.92	156.16	13.92	1381.68	398.95	17.12	1276.64	87.49	14.82
Tubificidae	2945.16	538.83	30.45	3017.88	362.28	37.28	2096.76	402.71	25.98	2686.60	295.67	31.19
S. heringianus							12.12	12.12	0.15	4.04	4.04	0.05
Enchytraeidae												
P. affinis	606.00	69.09	6.27	181.80	33.19	2.25	242.40	66.38	3.00	343.40	132.46	3.99
Pelecypoda	351.48	77.61	3.63	169.68	22.67	2.10	278.76	96.96	3.45	266.64	52.83	3.10
Gastropoda	290.88	35.34	3.01	48.48	22.67	0.60	84.84	30.90	1.05	141.40	75.47	1.64
Hirudinea												
Total Animals	9671.76	650.03		8096.16	477.40		8071.92	669.73		8613.28	529.29	

APPENDIX 13. (continued)

Depth Zone: 12 meters

Taxa	North Region $\bar{X}$	North Region S.E.	North Region %	Middle Region $\bar{X}$	Middle Region S.E.	Middle Region %	South Region $\bar{X}$	South Region S.E.	South Region %	Total $\bar{X}$	Total S.E.	Total %
Chironomidae	957.48	163.06	13.93	1527.12	232.66	23.77	351.48	44.53	17.16	945.36	339.43	18.48
Naididae	824.16	345.26	11.99	981.72	363.80	15.28	303.00	66.38	14.79	702.96	205.09	13.74
Tubificidae	1793.76	545.94	26.10	2436.12	789.76	37.92	484.80	201.90	23.67	1571.56	574.15	30.73
S. heringianus							24.24	14.84	1.18	8.08	8.08	0.16
Enchytraeidae												
P. affinis	1236.24	73.22	17.99	606.00	57.49	9.43	496.92	35.34	24.26	779.72	230.42	15.24
Pelecypoda	1357.44	288.47	19.75	702.96	174.17	10.94	254.52	70.15	12.43	771.64	320.23	15.09
Gastropoda	654.48	82.20	9.52	121.20	50.70	1.89	133.32	40.20	6.51	303.00	175.77	5.92
Hirudinea												
Total Animals	6872.04	1250.12		6423.60	1312.38		2048.28	225.45		5114.64	1538.64	

Depth Zone: 15 meters

Taxa	North Region $\bar{X}$	North Region S.E.	North Region %	Middle Region $\bar{X}$	Middle Region S.E.	Middle Region %	South Region $\bar{X}$	South Region S.E.	South Region %	Total $\bar{X}$	Total S.E.	Total %
Chironomidae	109.08	44.53	0.91	169.68	61.80	3.21	327.24	91.10	4.68	202.00	65.02	2.50
Naididae	303.00	91.90	2.53	193.92	102.12	3.67	666.60	50.70	9.53	387.04	142.89	4.79
Tubificidae	1296.84	402.25	10.81	1018.08	186.19	19.27	1830.12	361.27	26.17	1381.68	238.22	17.07
S. heringianus	2133.12	265.12	17.78	60.60	38.33	1.15	181.80	46.94	2.60	791.84	671.55	9.79
Enchytraeidae												
P. affinis	4714.68	430.39	39.29	2775.48	248.68	52.52	1987.68	269.24	28.42	3159.28	810.27	39.04
Pelecypoda	3114.84	308.76	25.96	909.00	195.43	17.20	1733.16	406.79	24.78	1919.00	643.52	23.71
Gastropoda	254.52	44.53	2.12	145.44	56.20	2.75	206.04	56.20	2.95	202.00	31.55	2.50
Hirudinea	12.12	12.12	0.10				12.12	12.12	0.17	8.08	4.04	0.10
Total Animals	11998.80	1057.47		5284.32	655.32		6993.24	740.36		8092.12	2014.67	

APPENDIX 13. (continued)

Depth Zone: 20 meters

Taxa	North Region $\bar{X}$	North Region S.E.	North Region %	Middle Region $\bar{X}$	Middle Region S.E.	Middle Region %	South Region $\bar{X}$	South Region S.E.	South Region %	Total $\bar{X}$	Total S.E.	Total %
Chironomidae	569.64	406.34	2.68	230.28	92.70	2.55	690.84	228.84	5.67	496.92	137.83	3.51
Naididae	727.20	727.20	3.42	48.48	29.69	0.54	84.84	41.10	0.70	286.84	220.43	2.03
Tubificidae	2217.96	1475.66	10.43	727.20	329.14	8.05	363.60	69.09	2.99	1102.92	567.31	7.79
S. heringianus	8023.44	4357.50	37.72	4423.80	464.29	48.99	1054.44	344.20	8.66	4500.56	2012.14	31.78
Enchytraeidae												
P. affinis	2024.04	490.30	9.52	1842.24	481.61	20.40	4132.92	359.23	33.93	2666.40	735.14	18.83
Pelecypoda	3623.88	2197.73	17.04	1454.40	542.36	16.11	5417.64	1211.18	44.48	3498.64	1145.80	24.71
Gastropoda	1018.08	693.44	4.79	218.16	73.22	2.42	363.60	131.38	2.99	533.28	246.01	3.77
Hirudinea	278.76	219.00	1.31	36.36	14.84	0.40				105.04	87.49	0.74
Total Animals	21270.60	12840.09		9029.40	1194.30		12180.60	1608.47		14160.20	3669.75	

Depth Zone: 25 meters

Taxa	North Region $\bar{X}$	North Region S.E.	North Region %	Middle Region $\bar{X}$	Middle Region S.E.	Middle Region %	South Region $\bar{X}$	South Region S.E.	South Region %	Total $\bar{X}$	Total S.E.	Total %
Chironomidae	521.16	165.52	9.15	327.24	154.02	3.87	1139.28	346.75	8.33	662.56	244.85	7.14
Naididae	12.12	12.12	0.21							4.04	4.04	0.04
Tubificidae	1005.96	176.26	17.66	521.16	159.87	6.16	412.08	105.66	3.01	646.40	182.52	6.97
S. heringianus	2642.16	310.54	46.38	3842.04	974.81	45.42	3514.80	277.04	25.71	3333.00	358.10	35.93
Enchytraeidae												
P. affinis	1187.76	199.70	20.85	2666.40	477.16	31.52	4605.60	358.00	33.69	2819.92	989.63	30.40
Pelecypoda	303.00	85.70	5.32	1030.20	396.46	12.18	3975.36	265.95	29.08	1769.52	1122.72	19.08
Gastropoda	12.12	12.12	0.21	24.24	14.84	0.29	24.24	14.84	0.18	20.20	4.04	0.22
Hirudinea	12.12	12.12	0.21							4.04	4.04	0.04
Total Animals	5696.40	653.53		8459.76	1821.89		13671.36	831.26		9275.84	2338.05	